

# The Blast Furnace *and* Steel Plant

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# The Blast Furnace *and* Steel Plant

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## What Can You Do?

THE Advertisers Club of New York, on April 7th, entertained Sir Charles Higham, of London, at luncheon. Although Sir Charles is now an Englishman he was born in Brooklyn, consequently he still has a high regard for the land of his birth. In his adopted country he chose advertising as a vocation and the degree of success he attained in this work is attested by the fact that, during the war, he won the title of Sir in recognition of exceptional service.

To the request for a speech he responded by relating experiences from his business life. In speaking of the characteristics of Americans he said, "What I like about you Americans is that you do not ask; 'What have you done?' but, 'What can you do?' "

This remark not only reflects a correct appreciation of the standard of appraisal in this country, but the phrasing of the remark is most apt. In our industrial life the valuation that is placed on one's services is reckoned not so much by past accomplishments as by present capabilities. Past performances can be used only as a criterion on which to base a judgment of the present.

Sir Charles Higham, today, is among those at the head of his profession, because he appreciated the significance of the sentiment he expressed.

# Physical and Chemical Structure of Ingots

**Defects in Ingots such as: Piping, Segregation, Liquation, Banding and Porosity Receive Consideration From a Metallurgical Viewpoint. Their Formation Studied**

By JOHN D. GAT\*

THE freezing of substances like steel is always accompanied by selective crystallization when some of the compounds solidify before the rest. This is usually connected with rejection by growing crystals of more easily fusible substances in some definite direction. In molds more fusible compounds are usually found along the axis of the ingots.

Steel passing from the molten state to room temperature shrinks very appreciably and proper means should be provided for taking care of this phenomenon. The top and bottom of the ingots cool first. This is entirely desirable at the bottom. The top, serving as a supply of metal for shrinkage, loses heat by radiation before the body of the ingot is solidified to form a solid crust. As the metal in the mold continues to cool and subsequently contract, a fresh supply of it is drawn from the top and, after a certain time, a cavity of considerable dimensions is formed.

Only three constituents of a very complicated system are liable to be rejected to the center, slag, sulphides and iron carbon alloys richer in the latter element than the body of the ingot. This means that discontinuity created by crystallization is always composed of solid substances while the defects attributed to solidification in general are voids.

It is necessary to mention that freedom from pipe is a function of the action of several factors, and none of these alone can be held responsible for defective metal. Steel mills desiring to simplify operating procedure standardize as many variables as is consistent with shop practice and concentrate their attention mainly on teeming temperature.

Of all three types of molds selected for this set of experiments the relation between teeming temperature and freedom from pipe is strikingly demonstrated.

One of the most undesirable conditions of pipe formation which can be met is shown in Fig. 7. The ingot in question was cast in a mold provided with a very efficient hot top, but with an incorrect cross section of walls. It was "bridged" at the top too soon so that the shrinkage cavity could not be fed by the metal contained in hot top as a consequence a void was formed in the middle of ingot.

Ingots of this type are most undesirable due to the heavy losses involved in their use. Not only is the presence of visible pipe itself objectionable, but it is at the same time an indicator of segregations resulting from crystallization. Any ingots which show pipe should be unconditionally rejected. This is an established rule and manufacturers prohibit any metal leaving their plants. It is easy to see the continuous pipe, in Fig. 8.

Mill inspectors stationed at Blooming Mill shears can easily remove defective metal by successive shearing until "shear drag," associated with the presence of pipe, is no more. By cropping off the shrinkage cavity of ingots as shown in Fig. 7, many feet of per-

fectly sound billet will be obtained before the dangerous secondary pipe will show its presence. If the lengths into which the billet is cut are short enough, careful inspection will catch the pipe, but with greater lengths there is always a danger of some of it being left undiscovered and the billet rolled to final size.

Consumers of steel are protected from the probability of getting piped metal by the ease with which it can be detected. With the present mill practice the size of ingots is so large that unless very heavy sections are rolled inclusions of secondary pipe are long enough to extend for more than one finished bar, and of course for more than one multiple, into which they are cut. In other words there is always a chance to observe a freshly sheared end on which the "drag" caused by the pipe cannot be mistaken. This test seems to be infallible when a large pipe is encountered and with experienced inspectors it is apparent to almost to a microscopic pipe, although when the drag is less than one-eighth of an inch it is necessary to check the observations by microscopic examination of a polished but unetched sample, cut perpendicularly to the axis of the bar. Bad pipe will appear as in Fig. 9 which is an extreme case. Usually this defect is less pronounced, but in every case before passing final judgement, several specimens should be cut from the suspected bar and examined, to see if non-metallic inclusions suspected for pipe form a continuous thread.

The facts just outlined presupposes killed steels which include all alloy steels made in the United States. Effervescent, open metal, does not contract on solidification, but often expands and instead of having one large central cavity it is filled uniformly with smaller blow holes which may be filled with gas or contain solid inclusions, chiefly slag. On rolling any air holes are welded while slag inclusions are elongated into stringers of different sizes, and are distributed all over the body of metal, so that the question of pipe does not arise.

Crystallization interferes considerably with the uniformity of composition of ingots. It is largely controlled by the same factors as in the formation of pipe, hence one supposes that the precautions which are observed for reducing pipe will help in eliminating the undesirable conditions which are created by gradual solidification. Experience supports this view. All that can be said about control of location and size of pipe can be repeated in regard to those defects created by crystallization; segregations.

## Segregation in Ingots

If the presence of solid pipe is objectionable as interrupting the continuity of the metal, segregations introduce less visible, but almost as objectionable differences in composition. From the three substances which are liable to be rejected, on solidification toward the center, alloys rich in carbon occupy a predominant position as far as segregations are concerned. In a great majority of cases two others, sulphides and slag, forming visible pipe, serve as indi-

\*Metallurgical Engineer.



cators of the proper amount of croppage necessary for production of sound metal, but on rare occasions, especially with high, (in the neighborhood of one per cent) carbon steels, crystallization fails to segregate them close enough to cause "shear drag" on shearing. This steel will pass inspection, but the presence of an alloy, sometimes about twenty points higher in carbon, in the center of a bar is liable to create trouble in the heat treatment of the finished piece.

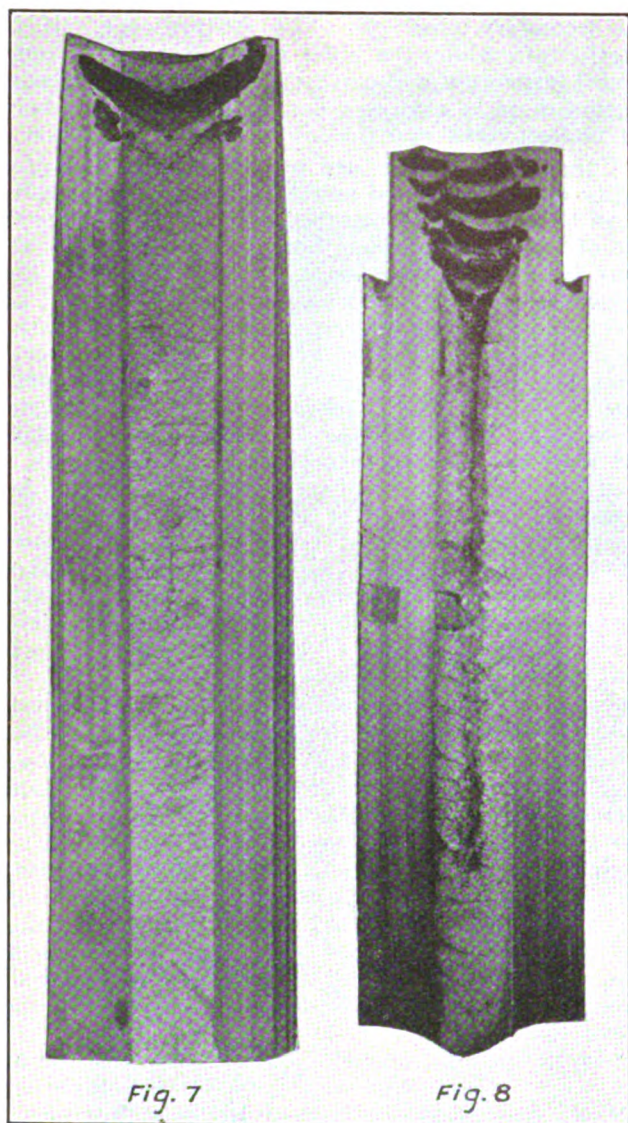


Fig. 7

Fig. 8

FIG. 7—Secondary pipe. Incorrect mold design. FIG. 8—Ingot poured in straight wall mold using hot top.

Segregations, like pipe, do not extend the whole length of the ingot. The removal of the pipe usually eliminates segregation, but in those cases where one wants to check the uniformity of composition of a bar the presence of segregations has to be revealed in some way, other than by drilling over the whole surface of a section. This can easily be done by grinding the surface under investigation and immersing it in acid for a period ranging from ten minutes to an hour. Fifteen minutes in concentrated boiling hydrochloric acid will give a satisfactory developed structure in a great majority of cases. A difference in corrodibility causes areas containing higher carbon or sonims to dissolve faster.

The surface thus produced corresponds exactly with the actual distribution of carbon. Taking successive cuts along a bar, under investigation, and subjecting it to this "porosity" test will show the extent of segregation and one analysis from the center of the corroded area will show the degree of it.

Commenting on this defect it is a fact that no steel ingot made under present conditions is entirely uniform in composition because crystallization exerts influence, besides that of carbon, sulphur and phosphorus. In properly designed molds, segregation is in the center and extreme upper part of an ingot, as it is shown on Fig. 10. The latter case is welcomed by steel men because it gives an opportunity to remove undesirable metal by a moderate amount of croppage not exceeding the usually adopted minimum for alloy steels. Center segregations are considerable more troublesome and sometimes require scrapping of an appreciable tonnage, but this is in case of high carbon steels only. There is, seemingly, some relation between the carbon content of metal and the amount of the latter which can be rejected on crystallization. This relation is not a straight line equation, being of a higher power, so that in steels with medium carbon content the degree of segregation to the center is so small that, disregarding the possibility of its presence, it can be entirely dismissed from consideration.

### Liquation

Segregations should be distinctly separated from peculiarities of composition caused by liquation. It is not exactly clear whether attributing it to solidification is well warranted or should be connected with later stages of manufacture. This defect is observed chiefly in nickel steels, where certain areas, almost always of microscopical dimensions and distributed all over the metal, contain considerably larger percentages of this element. There are no means to discover this interesting feature in low carbon steel and the only method for establishing its presence is to carburize the specimens. Liquation shows itself, after carburizing and slow cooling, as in Fig. 11. From a practical standpoint this defect has but little importance because, being limited to one class of steels only, it occurs very seldom. Minute areas of high nickel alloy distributed comparatively uniformly do not affect the properties of steel to any appreciable extent in the hot rolled state. In heat treating they cause warpage. A very considerable lowering of the critical points, induced by nickel, destroys thermal equilibrium among grains of steel and in heat-treating tends to increase the warpage. The McQuaid Ehn test, on the basis of which most of the carburizing steels are bought, serves as a means for the discovery of liquation in this type of metal. The carburizing of badly warping steels, containing nickel, always shows whether liquation has caused the warping.

One is tempted to believe that liquation is not entirely unrelated to a somewhat hurried making of some heats, but at the same time there is no positive evidence that it cannot be attributed to phenomena taking place after the steel leaves the furnace. No numerical values can be given regarding its influence on the properties of metal, because the field of observation, due to the very uncommon occurrence of this defect, is exceedingly narrow.

If the term "porosity testing" was placed in quotation marks when speaking of segregations, it has to be used in its direct sense in discussing some of the



peculiarities of the crystalline structure of steel ingots and products made from them. Progressive solidification taking place in molds cannot always proceed along the lines conducive to the greatest uniformity of ingots. Under ideal conditions the material solidifies from the bottom up. Crystals grow uniformly pushing before them less refractory constituents of liquid metal which are segregated near the top and are removed by proper cropping. The inside of such an ingot is filled with crystals of about the same size and orientation, hence any section of such an ingot will have approximately the same physical characteristics and identical composition.

A brief analysis of phenomena passing under the general name of solidification will help to explain the deviations from the perfect ease just outlined. In the first stage, when liquid metal comes in contact with the cold walls of the molds it results in the formation of a skin of long acicular crystals directed from outside of the center. When their thickness reaches such an extent that a considerable lowering of the speed of heat transfer begins to be noticeable the metal, instead of forming long crystals on the skin begins to crystallize normally, i.e. equiaxially. Primary, dendritic, crystallization is followed by the changes in interdendritic space and then by allotropic transformations.

From a practical standpoint the attention of an observer should be directed not to basic phenomenon, crystallization, but to the secondary features; rejection of more fusible constituents, size of dendritic formation and orientation of crystals forming the center of ingots. With the standard type of molds changes in solidification are produced slightly by composition of steel and very pronouncedly by temperature of the metal. With incorrect pouring temperature, formation of the skin occurs with a speed permitting full rejection of more fusible components. If at the same

time the center of the ingot remains liquid long enough to permit the upward elimination of them, no trouble will be encountered, otherwise they will be segregated roughly along the inside border of the skin.

Solidification of the center of the ingot is again a function of the temperature, though some other conditions may show their influence quite pronouncedly. Taking the case of an ingot which was bridged from the supply of liquid metal, hot top, like those represented on Fig. 7, it is not difficult to see that normal crystallization would be seriously handicapped. Shrinkage of freezing metal cannot be compensated from above and will be taken care of by the formation of microscopical voids between crystals. Too high a temperature is likely to increase the size of dendrites to such an extent that the ordinary amount of work to which steel is subjected is rolling, especially when quite heavy sections are required, will not be sufficient to restore uniformity of the metal, and its strength will not be considerably reduced by cementitic or ferritic envelopes surrounding normal crystals. Improper temperature is liable to segregate easily fusible impurities, high carbon alloy, slag and sulphides, somewhere around the center, but not so close as to form a visible pipe.

### Porosity

Several terms were devised to cover this abnormal condition of ingots, but they can be given a generic name, which at the same time covers the test by which they are revealed, porosity. It is unnecessary to mention that all defects are not discernible on the surface of sections cut perpendicularly to the axis of ingot neither by a naked eye or by a microscope. Selective action of acids on heterogeneous agglomeration forming an ingot of steel furnishes a powerful tool. A simple immersion of the smoothly ground section of an ingot in acid will develop on its surface a design

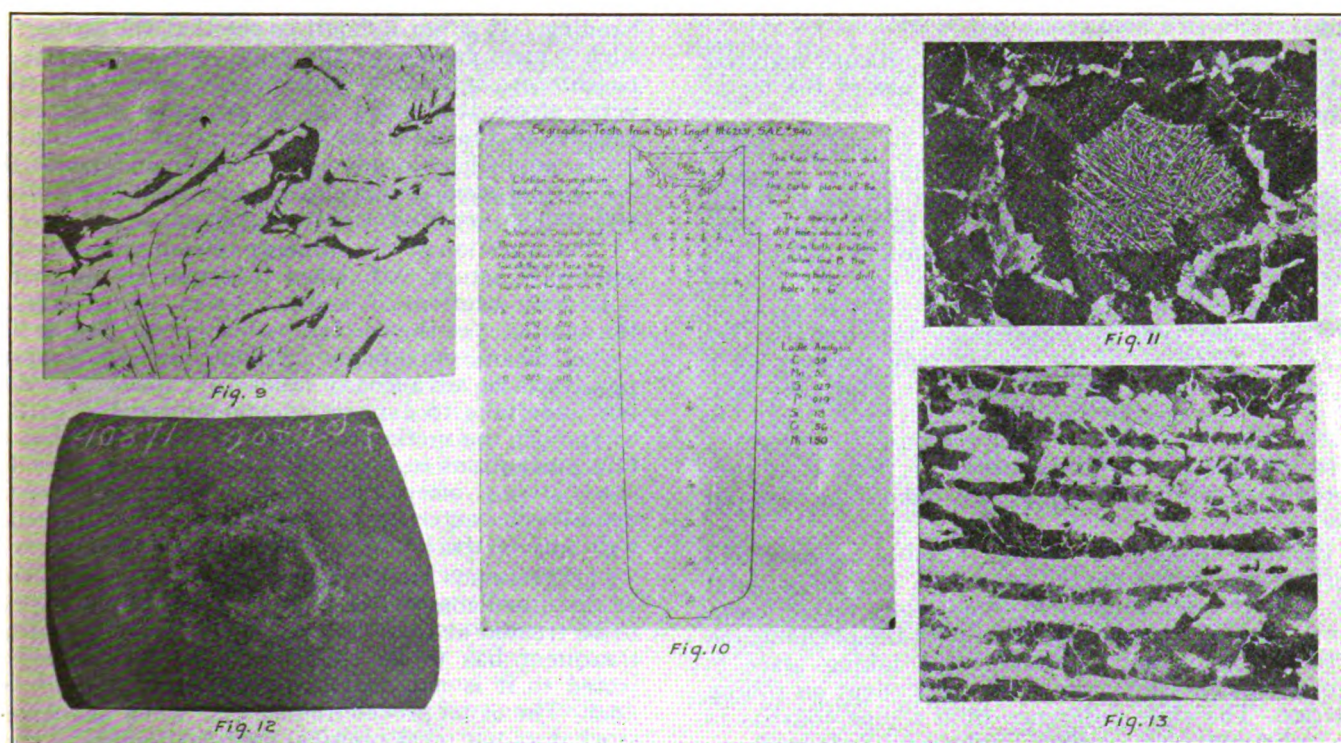


FIG. 9—Badly piped steel. Cross section of 13/64 in. bar x 100. FIG. 10—Usual distribution of segregations in a correctly made ingot. FIG. 11—Liquation as shown after carburizing and slow cooling. FIG. 12—Badly pourous specimen taken from 4 in. x 4 in. billet. FIG. 13—Badly banded steel after a full anneal.



showing plainly the real state of metal. Conditions leading to porous, after pickling the surface, may be justly called invisible pipe, and may be considered as subject to the same laws of distribution and intensity.

The effect of the porous condition of steel on its physical properties defies any generalization. Before forming any opinion it is absolutely necessary to know with what type of porosity one deals and what was the heat treatment of the piece of steel on which porosity was observed. In a steel, porosity which is caused by strong concentration on non-metallic inclusion, Fig. 12, one has to expect that a test cut perpendicularly to the direction of rolling through the porous zone will have lower elongation and reduction of area than the sound part of it. In a moderate case of the same kind, tensile strength results will not be convincing while with slight porosity, no difference from sound metal would be observed.

With steels yielding a pattern of excessively large dendritic structure, sometimes accompanied by fissures, rejection should be based on the use of it after rolling. If a substantial amount of work is to be done the steel should be released without any compunctions, because an excessively large structure will be completely destroyed together with all its undesirable features while microscopical cracks causing fissures will be perfectly welded, due to their absolute freedom from oxidation and minute size. This contention is supported from two points of view. A billet showing decided porosity of this type and with many fissures will, after rolling, give a perfectly sound bar. A bar which does not show any traces of porous structure after rolling may when upset show this feature quite pronouncedly.

The porosity test is, comparatively new, so that one is not justified in forming a positive opinion regarding its value as a means of selecting the best material. The experimental stage of it is at present sufficiently advanced to warrant some tentative conclusions.

In specifying a porosity test, to procure material with a maximum strength, the final use of the metal plays a very important role.

If steel leaving the mills is of heavy section, and a very moderate amount of work is done on it before being put into finished article, strict attention to all types of porosity is recommended. In small sections porosity of the second type is eliminated by rolling and attention should be concentrated on porosity caused by non-metallic inclusions. It is necessary to mention that the latter type is considerably less frequent because the cropping of the visible pipe removes, in a majority of cases, sections of ingots in which segregations of non-metallic inclusions are excessive. On smaller sizes the absence of pipe assures the freedom of steel from porosity. In heavy sections it is connected with non-metallic porosity, but in one case out of a hundred.

Etching sometimes reveals, besides porosity and segregations, small checks or cracks located without any definite orientation and found along tested specimens. These have nothing to do with the phenomenon of solidification, and crystallization, taking place in ingot molds, as they are entirely dependent on rolling practice. The chief difference from a pipe consists in the unlimited field of distribution and independence from any kind of abnormalities in the composition of the steel. The very best steel may, though exceedingly seldom, have them. They may occur, in some or in all

blooms of an ingot, but as a general rule, those blooms which have checks have them over the whole length, while in case of pipe, or segregations, the distribution is not uniform.

The reason these defects do not excite any interest is firstly, the very rare occurrence of them and secondly, the fact that these checks are found, with only slight deviation from standard rolling practice, in quite heavy sections. A very marked digression from normal practice is necessary to produce them in bars, less than about 2 in. diameter. Rolling to smaller size entirely closes them and, finished bars after pickling, appear perfectly sound though the original billet from which they are made might be full of checks.

In the study of the influence of rolling on the quality of steel it would be proper to omit all purely mechanical imperfections such as defects connected with the surface, size, and shape of bars. A steel can be modified by rolling in two ways only, banding may be introduced and the appearance of fracture changed.

### Banding

Banding appears to be one of the most disputed questions in steel metallurgy, both from theoretical standpoint and practical importance, and is generally understood as stratification of the ferrite and pearlite. The origin of this peculiarity is not quite clear, but the contention that banding is produced by rolling is supported by the observation that forging bars perfectly free from this feature at too cold a temperature causes them to become banded. Once produced banding cannot be eliminated by any amount and kind of heat treatment and only a sufficient amount of work can break it up. This is the reason why nickel steel used for forging is more prone to banding than any other type. It is often advisable to design forging dies in such a way as to produce a possible maximum deformation.

Fig. 13 shows a typical example of very pronounced banding. It is not difficult to see that the strength of such a steel cannot be the same as when ferrite and pearlite are intimately mixed, especially when transverse stress is applied as for example, in gears cut parallel to the direction of rolling. Its resistance to loads, applied longitudinally, is somewhat lower than for normal steel, though elongation, reduction of area and impact are appreciably higher.

The question of the influence of rolling on the character of fracture of finished bars can be approached only with caution. Classification of steels based on the character of the fracture is very new. It has been, by no means universally adopted, and while certain points can be advanced in favor of it, the writer would not undertake to express an opinion neither in favor or against the method. It can be only said that certain precautions in manufacturing procedure result in steel giving, after annealing, a fracture possessing definite characteristics, which cannot be associated with any of the known peculiarities of steel.

Digressions from specified heat treatment cannot be discussed comprehensively in a few pages and have to be treated at their own value, i.e. an incorrect heat treatment has to be condemned, but the steel subjected to it is not necessarily an unsatisfactory product. The usual procedure in a case when heat treated stock does not meet physical specifications is to return it for retreatment and charge the manufacturer with its transportation both ways. Before doing so one has to be certain that the testing is done by a properly



qualified person and the accuracy of the testing machinery is above reproach. The only reason a shipment should be sent directly to the scrap pile is in case the steel is burned.

### Burned Steel

Burning should not be confused with overheating. The first ruins the steel entirely, the second is easily remedied by proper modifications in heat treating. Their recognition does not present any special difficulty and should be made with the aid of a microscope. The usual method for ascertaining the presence of burning, etching with Stead's reagent for phosphorus segregations at the grain boundaries, will seldom give, in case of alloy steels made in the United States, any positive indications, due to usually low phosphorus content. After polishing, but before etching, the surface of specimens should be searched for the presence of iron oxide with a low power, about 50 diameters, microscope. Higher powers are less suitable because oxide particles are few, very widely scattered and are difficult to find. After locating one it is investigated with increasingly higher magnifications until one is certain that its true nature is iron oxide. This is an unmistakable sign of burning and the steel should be rejected unconditionally.

These few simple tests evolved in the last few years give to the user of steel a reliable tool for revealing its properties. Conclusions drawn from them and the interpretations of data are based on the experience of many steel manufacturers. They, to a certain extent, are a consensus of the opinions of a majority. A word of warning should be sounded regarding the interpretation of tests. Intimate knowledge of a subject is necessary for its proper understanding. If only an occasional test is made and the results do not correspond to the desired specifications, it is better to consult the manufacturer, before condemning the material. Daily handling of hundreds of samples, usual routine work in the mills, develops a certain procedure in manipulation and interpretation, difficult to duplicate, but very necessary for obtaining reliable results. Reputable steel companies do not follow uncertain policies, and on innumerable occasions have proved this by indicating ways for eliminating troubles with supposedly unsatisfactory steel, or by replacing it with metal in exact accordance with the specifications, when the defects were really present.

Looking backwards a decade or so, one wonders what kind of material the manufacturers sold, and becomes uneasy thinking what would happen if the requirements which may be submitted in the next quarter of a century would be entered in specifications of today. There is no doubt that what is required at present will appear to the next generation of metallurgists as primitive, as the specifications submitted to Mr. Carnegie at the beginning of his career, seem to us. Continuous and intensive work goes on uninterruptedly in all progressive steel plants developing new testing methods and improving manufacturing processes, work intimately intermeshed with all phases of steel making, but not apparent to outsiders. The general public hears only about results. When a test points to almost indisputable conclusions it is submitted to the public for approval and for verification in a still larger field than in the steel plants alone. Points of approach to a given subject are innumerable, but only a few of them are correct, and are therefore merely an infinitesimal part of the work done by the steel companies. The fulfillment of specifications is

only a small part of work of reputable steel plants. Every order of steel undergoes a host of tests besides those required in the specifications, and which are often considerably more difficult to pass than the simple requirements of steel consumers. Often a heavy loss is voluntarily taken in order to give a better quality than asked, and doing this as a matter of honest daily routine.

The writer wants to express his gratitude to Messrs. P. L. Macklin and C. C. Snyder, of Metallurgical Laboratory of United Alloy Steel Corporation, for preparation of some of the photographs illustrating this paper.

### The Dutch Turn to Making Iron

The rapid growth of the iron industry in the Netherlands during the past three years is revealed in a trade bulletin issued today by the Iron and Steel Division of the Commerce Department.

Although official figures are lacking, it is estimated that during the fiscal year which ended in March 1927, Dutch blast furnaces produced in the neighborhood of 200,000 metric tons of pig iron. While this figure is relatively small, it is striking in view of the fact that prior to 1924 the iron industry in the Netherlands was non-existent.

The decision of the Dutch to establish an iron industry of their own, according to the bulletin, came about as a result of the rigid supervision exercised by the belligerent countries during the war over iron and steel exports. The Royal Dutch Blast Furnaces and Steel Works, known to the trade as "Hoogovens" was organized in 1918 with a capital of 25,000,000 florins of which the Dutch government participated to the extent of 7,500,000 florins. A plant was built near Amsterdam which began operations in 1924. During the fiscal year 1924-25 Dutch plants produced 106,000 metric tons of pig iron which was increased to 109,000 the following year. A second blast furnace was blown in on January 8, 1926, after which production increased markedly. The total capacity of the plant is over 235,000 metric tons per annum.

The iron ore used in the Dutch plant, the bulletin disclosed, comes from Sweden, France, Spain and Algiers, long-term contracts having been made with mines in all four of those countries. For its coal the Dutch company has a source of supply in the Linberg mines and it has acquired control of several German mines which assure sufficient coal for many years to come. The limestone used comes from Belgium where the Dutch own an important pit.

The importance of the Dutch iron industry in world trade, the bulletin points out, is out of proportion to the actual production of the Dutch plants, owing to the fact that practically the entire output of pig iron is exported. The United States is by far the largest buyer of Dutch pig iron. In 1925 out of 95,000 tons exported, 52,000 tons were shipped to this country while during the first ten months of 1926 out of total exports of 92,000 tons, 57,000 tons represented exports to the United States. Italy, Switzerland, Denmark, and Sweden also take considerable quantities of Dutch pig iron.

The Rust Engineering Company has secured a contract for designing and constructing a hot blast stove installation at The Delaware River Steel Company's blast furnace plant at Chester, Pa.



# The Steel Mill at the Ford Plant

## Description of the Plant as a Whole. The Merchant and Blooming Mill Motors and Control. Projected Developments and Equipment

By T. HARVEY†

**L**OCATED on the River Rouge, approximately 12 miles west of Detroit and southeast of Dearborn, Mich., is the world's greatest automobile plant, employing approximately 70,000 men. This plant was formerly known as the River Rouge Plant of the Ford Motor Company, but has recently been called the Fordson Plant. It was established about 10 years ago, and not only contains the main automobile motor assembly plant, but in addition, manufactures Fordson tractors, operates its own blast furnaces, main a.c. power plant, body plant, lumber mill, coke ovens, and by-product plant, wet-process cement plant, steel plant, and rolling mill, electric melting furnaces, paper mill, sintering plant, locomotive shops, and glass factory, all of which make it one of the world's largest industrial establishments.

The entire plant covers more than 1,400 acres and includes 1½ miles of dock frontage located on a channel deepened some years ago to furnish direct access to the Great Lakes and ocean trade routes. With development of this project, the company obtained a fleet of lake and ocean freighters for the transportation of raw materials, including iron ore from the Ford mines in the upper lake region, lumber from the immense forest tracts owned by them in the Iron Mountain (Mich.) district, and for the transportation of automobile parts for assembly in foreign plants both in Europe and South America.

Linked with this water transportation is the Detroit, Toledo and Ironton Railroad, which operates from the Fordson plant to the Ford coal mine property near Ironton, Ky., and which makes connection with practically all trans-continental lines of importance. In addition the Detroit and Ironton branch of the D. T. & I R. R. has been added to the railroad holdings. This latter road consists of a 13-mile stretch between Flat Rock and the Fordson plant. It has been completely electrified and is in operation for the purpose of developing Mr. Ford's ideas in regard to modern electric locomotive freight haulage and gas-electric passenger service.

In connection with this transportation system, storage capacity has been provided at the Fordson plant for 2,000,000 tons of ore and all the lime, coke, and coal required for the manufacture of pig iron.

### The Merchant Mill

The first unit of the Fordson rolling mill plant was put into operation in November, 1925, at which time the 14-in. merchant mill began rolling steel from purchased billets. This mill is operated by one 24-pole, 4500-hp., 67.5/110 rpm., 500-volt, d.c. motor. The power for operation of the motor is furnished by two 12-pole, 2000-kw., 400-rpm., 250-volt, d.c. motor-generators equipped with 500-volt insulation, and each driven by an 18-pole, 2800-kv-a., 400-rpm., 13,200-volt, 3-phase, 60-cycle, synchronous motor. Both motors

and generators are separately excited from a shop bus, the power for which is furnished from a substation containing a number of 1500-kw. synchronous motor-generators. The reliability of the source of excitation being thus assured, direct-connected exciters are not used with any of these motor generators. Two generators are operated in series to give 500 volts, for which voltage the mill motor is designed. The motor and motor-generators are installed in a glass enclosed and enameled tile walled substation, which is located inside and at about the middle of the main merchant mill building (Fig. 1). The substation contains two additional generators of the same rating. One of them is designed for use as a spare unit for either of the two sets mentioned above. The other is for use as a second spare for furnishing power at 250 volts to operate the auxiliary mill motors, and, if required, to furnish excitation for all the other motor-generators. The auxiliary mill motors for this particular mill consists of about 50-230-volt d.c. motors of the standard crane and mill type of various ratings from 7½ hp. to 100 hp. There are also a number of standard industrial type d.c. motors installed for operating cutting shears and other machines of similar type.

### Control for Merchant Mill Motor

The control board for the mill motor and the motor-generators is located in the same building, and is of the remote or semi-automatic type. The board consists of two parts, the main control board carrying twin-pull switches, with the usual indicating signal lights, for starting, stopping, reversing, and regulating the speed of the main motor and for starting and stopping the motor-generators. This board also carries all the instruments and the air circuit breakers necessary for controlling the feeder circuits handling the power supply to all the auxiliary motors. It is located on the main floor with the motor-generators and the main motor. The second part of the control board is the contactor and relay board, operated from the main control board, and located in the basement directly beneath it. It carries all auxiliary contactors, protective relays, timing relays, accelerating relays, etc., such as are standard equipment for automatic control panels of this type. On the same floor with the board are located the motor-operated field rheostats for each d.c. generator and synchronous motor, the field rheostat for the main motor; and the main d.c. circuit breakers, which are mounted on an angle iron framework in a very compact arrangement. There is a total of 12 of these breakers of the high-speed type rated 12,000 amperes, 500 volts each. The breakers have been installed as an integral part of the d.c. bus structure, which is supported from the ceiling of the basement directly under the machines for which it carries the power supply. All of the a.c. oil circuit breakers are of the cell-mounted type and are installed in the center of the basement. All high-

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tension cables, as well as d.c. cables, are located underground in conduits. The entire substation is so compact and at the same time so accessible that its arrangement may be referred to as a model for such installations.

When the desired combination of motor-generators is running the operator pulls the forward or reverse control switch as desired, which applies field to the mill motor, closes the proper d.c. breakers, and gradually applies field to the d.c. generators, which automatically brings the voltage at the motor terminals up to, and maintains it at, normal value. If it is desired to stop the motor, the stop-control switch is operated, whereupon the d.c. breakers open, the d.c. motor field and the driving generator fields open, and the motor-operated rheostats are automatically returned to the corresponding "Off" position. If the breaker in the mill motor circuit opens on overload it is necessary for the operator to pull the stop switch before restarting, and the motor will not restart unless the rheostats are in the proper "Off" position. When operating in the forward direction, if it is desired to roll at a speed above 67.5 rpm., the operator adjusts the motor field by means of a control switch to give the desired speed.

If it is desired to reverse the operation of the main motor the reverse control switch is pulled, whereupon the motor field rheostat runs to the full-field position automatically, and the generator field rheostat runs through its range to the reverse position, so as to give normal voltage of reversed polarity at the motor terminals. The control is not designed to furnish a higher speed than  $67\frac{1}{2}$  rpm. in the reverse direction. If it is desired to operate below the normal low speed, i.e., normal voltage and full field on the motor, the operator pulls the low-speed switch and adjusts the generator voltage to give the desired speed. This adjustment may be made in either forward or reverse direction.

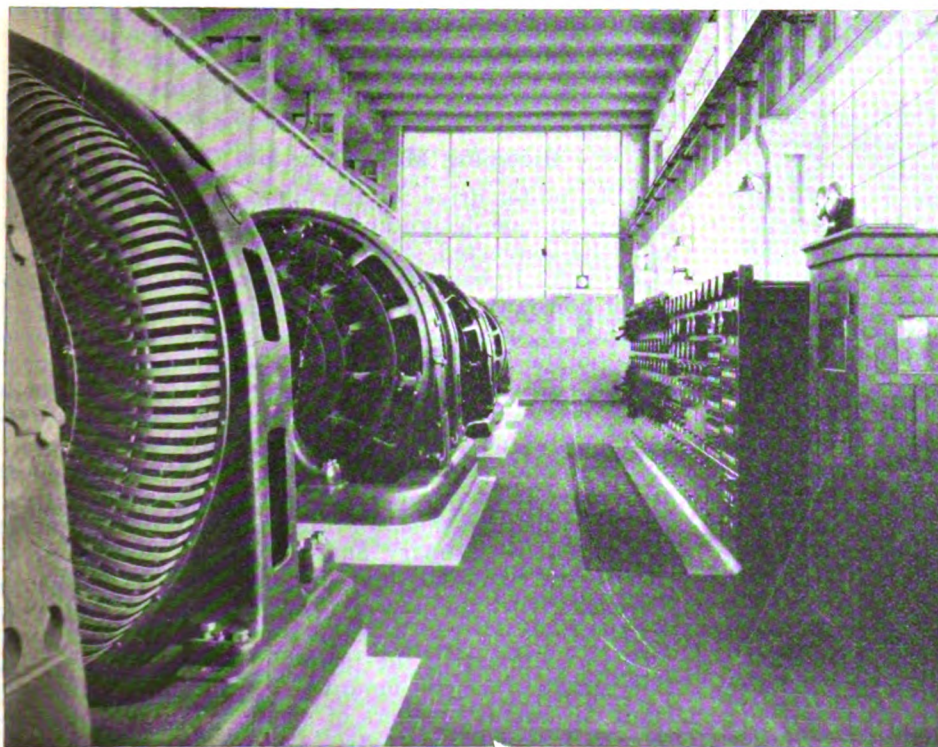


FIG. 1—The motor room of the merchant mill, showing the four 2000-kw. motor-generators and the main control board.

The control equipment referred to provides the following automatic features:

#### Synchronous Motors—

1—Start the shop supply motor-generator selected, and start the driving combination selected if the proper conditions exist.

2—Prevent the starting of a motor generator if:

- (a) The a.c. line pressure is below a safe operating value.

- (b) The motor-generator or the mill motor has been shut down by some protective device.

- (c) Prevent the starting of the driving combination if the shop bus is not energized.

3—Shut down a motor-generator if:

- (a) The equipment is subjected to harmful over load or to short-circuit conditions sufficient to require inspection, adjustment, or repair, before being placed in service again.

- (b) The field of the synchronous motor should fail.

- (c) The motor-generator should tend to over-speed.

- (d) A bearing should tend to overheat.

- (e) The starting sequence should not be properly completed.

#### D.c. Generator and Mill Motor—

4—Prepare to start the mill motor if all the d.c. breakers are open except the proper shop breakers, and if the motor field and the driving generator field contactors are open; if the mill motor field rheostat is in the full-field position and the driving generator field rheostat is in the zero field position.

- (a) Apply field to the mill motor.

- (b) Close the proper d.c. breakers.

- (c) Close the driving generator field circuits.

- (d) Build the generator voltage up to normal and then hold normal voltage up at the motor terminals.

5—Shut the motor down if:

- (a) The equipment is subjected to excessive d.c. over-load in either direction.

- (b) A bearing should tend to overheat.

6—When the mill motor is shut down, run the d.c. motor rheostat to the full-field position and run the generator reversing rheostat to the zero field position.

Normally the main mill motor operates at constant speed, this speed depending upon the product being rolled. It is designed to operate from its maximum speed forward (110 rpm.) with weakened field, to its full speed of  $67\frac{1}{2}$  rpm. in the reverse direction. Reversing, however, is done only in an emergency and the motor field rheostat automatically runs to the full-field position before the motor can reverse.

#### Operation of Merchant Mill

A brief discussion of the operation of the 14-in. merchant mill above referred to will be of interest. This mill receives 4 in. by 4 in.,



5 in. by 5 in., and 6 in. by 6 in. billets 14 to 15 ft. long and converts them into rounds and squares from  $\frac{7}{8}$  to 3 in. in thickness, or to an assortment of flats of equivalent sizes. Two heating furnaces are employed in supplying heated billets for the mill; they have 16 ft. by 40 ft. hearths and at the present time are being fired by fuel oil. The fuel that will ultimately be used in these furnaces is coke oven gas. The furnaces are equipped with the usual mechanical devices for charging and discharging billets.

The first group of roll stands consists of six pairs of rolls arranged in tandem, so that a bar never passes more than once through any given pair of rolls. This method of rolling is the well known continuous process, and was adopted by the Ford Motor Company because all the processes in its manufacturing plant are built around the principle of continuous operation.

The cooling bed which receives the finished product from the 14-in. mill consists of two sections, each 360 ft. long, and therefore capable of receiving hot bars of this length. After passing across the cooling surface the bars are grouped in multiple for shearing to the desired lengths for each particular product. After they are sheared they are assembled in batches on a scale and weighed. All of the mechanical equipment and conveyors for these rolls are driven by standard mill type motors, which are in turn controlled by magnetic control panels located on a balcony with the master switches. The number of operators in this mill is reduced to a minimum by the careful design of the mill and the special attention which has been paid to simplicity.

### The Blooming Mill

After the 14-in. merchant mill went into operation the next unit to start was the 42-in. and 32-in. special blooming mill designed to handle the small oval ingots having a corrugated surface which the Ford Motor Company have adopted for their practice in manufacturing high-grade alloy steels. The two blooming mills are driven by the same motor, which is equipped with double-shaft extensions and drives the 42-in. mill from one side and the 32-in. mill from the other. The mills are connected to the motor through heavy spiral bevel cut tooth gears enclosed in cast-iron cases having covers. An additional feature consists of large pinion housings between the gear housings and the roll stands, on each side of which are "breaking spindles" which are designed to let go in the event of trouble either in the gear or gear machinery (Fig. 2).

Stream lubrication of gears is employed throughout, the used oil being collected and returned to filters and then pumped to overhead storage tanks for redistribution. Unlike the usual blooming mill, the Ford mill does not reverse, but instead the roll stands are arranged in tandem formation. Again in this mill the material passes only once through each pair of rolls. Suitable roller tables between each pair of rolls automatically turn the ingot so as to present first one and then the other axis to the rolls. The opera-

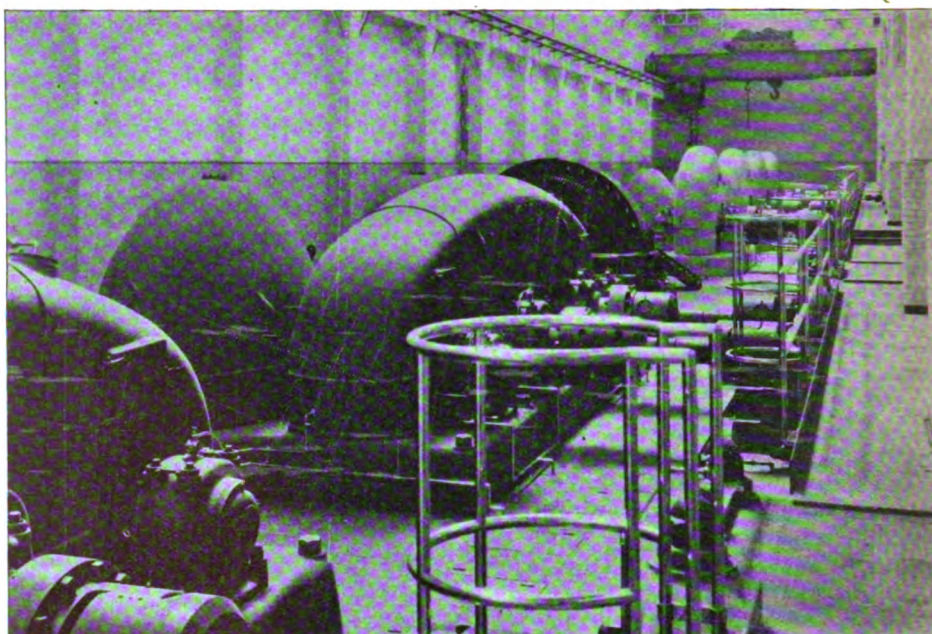


FIG. 2—Motor room of the 42/32-in. blooming mill, showing the 8000-hp. mill motor, and the reducing gears and couplings between the motor and the different stands.

tion of this mill is so completely automatic that very few men are required to run it. One simply sees an ingot arrive at the first stand of the rolls, then enter the first pass, being rolled in that pass and moving on to the successive stands with no apparent human effort being concerned in its handling. This blooming mill can produce upward of 125,000 gross tons per month—rolling small ingots weighing only 1500 lbs. It is obvious that such a large tonnage could not have been attained with such small ingots in any other than a continuous type of mill.

The soaking pits serving the blooming mill are of the usual type in which the ingots are charged with the initial heat of the open hearth and are allowed to soak to uniform temperature. The ingots are taken out of soaking pits and are placed in the tilting cradles, which discharge them into a special ingot run.

### Blooming Mill Motor and Control

The motor drive for this blooming mill is also of a rather unique design and consists of a 30-pole, 8000-hp. delta-connected, 3000-hp., Y-connected, 240-rpm., 13,200-volt, 3-phase, 60-cycle slip-ring induction motor of constant speed design. The double rating is obtained by means of external stator winding connections on the terminal board; by changing these connections the stator winding is ready for operation in either delta or Y-connection on either 8000 or 3000 hp. This is not only the largest slip-ring motor of this type and voltage ever built, but is the only one of its type in operation, so far as the records indicate. The control furnished for the motor is divided into two parts, the primary and secondary. The former consists of hand-operated disconnecting switches of the usual type, and 15,000-volt, 500-ampere solenoid-operated oil circuit breakers of the full automatic type for controlling the incoming line to the motor. The breakers are cell mounted. Additional non-automatic oil circuit breakers of smaller rupturing capacity are provided for controlling the forward and reverse operation of the motor. A control pedestal or panel, an indicating wattmeter, watt-hour meter, con-



trol switch, and signal lamps are installed in the main motor room on the same floor level as the motor.

The secondary control consists of panels equipped with the necessary magnetic contactors for short-circuiting the starting resistance, current-limit relays for automatically controlling the contactors, and the necessary grid resistors, master switch and push-button stations.

When starting the motor it is first necessary to close the main oil circuit breaker by operating its master control switch. After this breaker is closed the motor starts on the simple operation of the master switch, either forward or reverse. This switch may be thrown immediately to the full running position, in which case the motor comes up to speed under automatic control of the current-limit relays; or, it may be operated slowly and the motor brought up to speed as slowly as desired. The motor may be stopped either by opening the main oil circuit breaker and returning the master switch to the "Off" position, or by the operation of one of the "Stop" push-button stations. In any case after the motor has been stopped the master switch must be returned to the "Off" position before it can again be started.

The equipment as now installed is designed to control the motor with its stator windings Y-connected so as to give an output of 3000-hp. When it is desired to increase the load and operate the motor for an output of 8000 hp. the external stator connections are changed on the terminal board to give delta winding, in which case it is also necessary to change the taps on the secondary slip-ring resistors. Likewise it is necessary to change the current transformers operating the current-limit relays, also those located on the main control panel which operate the oil circuit breaker relays and instruments, and to change the scales on the indicating instruments.

The secondary control equipment provides seven automatic current-limit acceleration points and one plugging point, with hand control from the master switch. Primary reversing is obtained by means of the solenoid-operated oil circuit breakers already referred to, which are also controlled from segments on the master switch. An undervoltage protective contactor is provided on the panel which prevents starting of the equipment upon return of power after a shut-down caused by over-load, or by failure of voltage while running, until the handle of the master switch has been returned to the "Off" position. The primary oil circuit breakers are closed from segments on a master switch, but may be tripped either from an "Off" position segment on the master switch, or by the opening of undervoltage protective contactors due to undervoltage conditions, or by the operation of stop push-button stations located at several points in the mill.

The main motor and master control panel are located in a fully-enclosed, well-lighted motor room, finished with tile floor, and white enameled walls and ceiling. Special care was taken in the design and finish of the motor and control so that they would conform to the high quality of finish given the mill motor room. A special paint finish of an attractive dark maroon has been applied to the motor frame, and all bolts, nuts, rails, etc., are nickel finished, as are in fact all such accessories on the entire blooming mill and merchant mill motor housings. The motor is also equipped with an electric heater, installed in

its frame, which is controlled by separate contactors located on the secondary control panel. This heater is used to maintain the motor windings at a reasonable temperature while the motor is out of operation on week-ends or holidays. This is done in order to avoid condensation of moisture on the windings, with possible resultant damage to the insulation arising from the high voltage (13,200), for which the motor is designed.

The mill auxiliaries for the blooming mill are driven by mill type motors ranging from 10 hp. to 70 hp. and controlled by magnetic contactor panels of the remote control type with master switches. All these control panels and operating switches are located in balconies at the side of the mill and overhead as was the case in the merchant mill.

A visitors' gallery has been installed along the west wall of the motor room, from which both the motor room and the blooming mill proper may be viewed. The motor room is heated and ventilated with washed air, the same scheme being provided for the air compressor room, the 14-in. merchant mill motor room and substation, and the 18-in. mill motor room which is now under construction. Every possible attention has been paid to the selection of all control equipment and to its installation and operation in order to attain the greatest possible safety and utility, coupled with the best appearance.

### Projected Developments

The next unit of the mill to be started will be the open-hearth building, construction on which began in February, 1925, and which is rapidly nearing completion. This department is located south of the rolling mill, at right angles to each of the merchant and blooming mills, and covers an area 1066 ft. long and 240 ft. wide. The building is 112 ft. high and is served by a mile of railroad tracks. Four tilting hearth type furnaces have been installed, the normal production from which will be 200 tons of ingots per 24-hour day, each. Space has been provided for the installation of six additional furnaces. The building being of concrete, glass, and steel construction, permits exceptionally good light and ventilation in the interior. Remote-controlled motor-operated window frames are installed in this building and in all the steel mill buildings so far constructed. Cranes of 125-ton and 175-ton capacity are operated on runways 56 ft. above the ground level. There are two floor levels in the building, the ground floor and charging floor, the latter being 21 ft. above grade. The charging floor, which is paved with fire brick, extends from the middle of the scrap-loading building to a point in front of the open-hearth furnaces and contains another mile of track. A 10-ton storage battery locomotive will operate on these tracks for all haulage inside the building. Normal production from each furnace per day (200 tons of ingots) will necessitate the feeding of 1000 tons of molten iron, 1000 tons of steel scrap, 200 tons of limestone, 50 tons of iron ore and quantities of alloy metals to 10 of these furnaces daily. Melting these materials will require the burning of 80,000 gal. of tar per day, or its equivalent in oil or coke oven gas. Heat losses will be reduced by passing the hot furnace gases through a regenerator and through a waste steam boiler before they escape into the atmosphere.

The open hearth department really consists of four distinct operating units, viz: scrap loading building,



charging building, pouring building, and boiler building. Electric magnet cranes will handle all scrap in charging box cars, and scrap steel either from the stock pile, or from various other departments of the Ford Motor Company. The boiler building contains vertical waste heat boilers from which the furnace gas escapes at 300-400 deg. F. The steam generated in these boilers will be used for general plant purposes. In the same aisle with the boilers are the limestone and ore bunkers. An automatic skip hoist, together with belt and shuttle conveyors, will carry this material direct from the railroad cars outside of the building to the bunkers, from which point the material will be fed to the charging box cars by conveyors and chutes, then mixed with scrap steel carefully weighed while in the cars and switched by electric locomotives to the open-hearth furnaces. The continuous process as used by the Ford Company is again fully in evidence.

The charging aisle is that portion of the building where the furnaces are charged with hot metal, scrap, limestone, etc. At the extreme end of this building is a 600-ton hot metal mixer. This will be filled with hot metal direct from the blast furnaces and will hold an entire day's production from one furnace. As metal is needed at the open-hearth furnace a large ladle resting on the scale platform will be filled by tilting the mixer mechanically. This ladle will then be taken by crane or electric locomotive to the open-hearth furnace and poured into it through a suitable spout with the assistance of a 15-ton crane. The scrap and other materials delivered in charging boxes will enter the furnace through any one of the five doors by means of a special machine. This machine, operated by one man, will handle all material composing one charge in a minimum period of time. Electric controllers for delivering the furnaces and operating the door lifts and furnace-reversing valves will be installed on this floor. These controls will be of the push-button, magnetic contactor type, similar to those furnished in connection with the auxiliary motors in the other mills already described.

The temperature of these furnaces will range up to 3200 deg. F. Twice in 24 hours the metal will be poured out of each furnace into a 120-ton ladle suspended from a 175-ton crane. The slag will be poured direct from the furnace into a slag car on the ground floor, and removed.

The pouring of ingots and the preparing of the molds will be the chief operations in the pouring building. Eight ingot molds will be placed in specially designed cars which will be grouped into trains capable of taking the entire heat, or 100 tons, from each furnace. The molds will be carefully cleaned before being filled and will be equipped with hot tops to allow for the shrinkage of the steel as the ingots solidify. Four ingots will be poured at one time from the bottom pour ladles. After the ingots have solidified and while still hot they will be taken to a stripper building located just outside of the main open-hearth building and loosened from the molds by an especially designed machine capable of stripping eight molds at one time. This briefly completes the description of the open-hearth operation.

One other department of interest is known as the rail salvage department. This is used for reclaiming the steel in rails which were removed from the D.T. & I.R.R. at the time it was taken over by Mr. Ford,

at which time a great many of the original rails were replaced by rails of heavier design. This department contains a rolling mill of five stands driven by an 800-hp. adjustable-speed, 480/525-rpm. full-load speed, 250-volt d.c. motor, automatically controlled. This motor is direct connected to the five-stand mill and also to two flywheels, and is non-reversing. The mill is used for reshaping and salvaging steel rails. Before reaching it they are put through a motor-driven shear equipped with one 450-hp., 100-rpm., 230-volt pedestal-type bearing, d.c. motor. The motor is controlled by a full-magnetic, non-reversing, controller provided with dynamic-braking resistors and the usual overload, open-field, and low-voltage protection. The rails are passed through this shear while heated and are cut into strips, leaving the center of the rail in approximately a round form which is then passed through the rolling mill and rolled to the desired shapes. The strips salvaged from the rails are cut up in short lengths and either remelted or used after machining for various manufactured parts.

The power for the electrical apparatus is all generated in the Fordson main power plant. This station contains six turbine generators, four of which were designed and built complete by the Ford Company's engineers and are rated 30,000 kw., 80 per cent p-f., 13,200 volts, 3-phase, 60 cycles. The other two are General Electric units, 12,500 kw., 80 per cent p-f., 4,600 volts, 3 phase, 60 cycles, which have been in operation for 10 years. These two machines have operated for periods of several months at a time at 25 to 40 per cent overload without shut-down except during week-ends and holidays.

In order to avoid the necessity for maintaining two separate main buses for the 4,600 and 13,200-volt systems it is planned eventually either to rewind the 4,600 -volt generators for 13,200 volts, and arrange the turbines for higher steam temperatures, or to replace these units with larger and more modern machines of 13,200 volts capacity.

Full acknowledgement of assistance rendered the author in preparing this article is due to F. Allison, former Electrical Engineer, and H. L. Maher, Electrical Department of the Ford Motor Company, who supervised installation of all the electrical equipment and had charge of its operation and maintenance; A. M. Wibel, Mechanical Engineering Department of the Ford Motor Company, who handled specifications and purchase of steel mill equipment; and F. B. Crosby, Electrical Engineer of the Morgan Construction Company, whose firm furnished the mechanical equipment and acted as consulting engineers for the entire project.

### Larger Field of Gas Utilization

The large increases in gas sales registered by the manufactured gas industry in the past ten years will shortly be overshadowed and eclipsed when the effects of the volume of business lying in the industrial heating field is felt, according to Alexander B. Macbeth, President of the American Gas Association.

The industrial heating business will come to the gas companies because of the efficiency of gas fuel. Mr. MacBeth claims. In addition, he feels that more and more stress is being laid on the indirect costs of using crude fuels, such as storage of fuel, danger of shortage, spoilage of product by smoke, soot, or smell.



# Factors Affecting Open-Hearth Refractories\*

An Analysis of Heat Transfer and Temperature, As They Affect  
the Refractories in the Melting Chamber. Water-cooling  
and Wall Insulation Play a Prominent Part

By B. M. LARSEN† and A. GRODNER‡

PART II

THE open hearth is a furnace of relatively low gas velocities and very high temperatures, with a shallow bath exposed to radiation from a large area of luminous flame and heated wall surfaces. It has not yet been possible to measure heat flow by convection and radiation directly, but calculations§ have indicated that about 90 per cent of the total heat is transferred by radiation, the remainder being assigned to convection transfer. In spite of the lack of definite data, it seems reasonably safe to assume that conditions are essentially determined by radiation heating.

Convection transfer to the bath occurs by direct contact with the main stream of gases in the zone of flame. The roof and side wall surfaces should receive little heat by convection; in a correctly designed furnace these surfaces are away from contact with the main stream of hot gases.

The bath receives radiant heat in two ways, by direct radiation from the flame zone, and by radiation from roof and wall surfaces. Part of all this radiant heat is reflected up to roof and wall surfaces and part of it is absorbed and transmitted through the charge or bath by conduction or convection.

The radiant energy received by the roof and wall surfaces may be divided into three parts: (1) Much of the heat is reflected down to the bath, without being absorbed; the remainder is absorbed as sensible heat in the brick, part of which is (2) conducted through the walls, and part is (3) radiated down to the bath or to other wall surfaces.

## Critical Working Temperature Range for the Melting Chamber

From the above results we may conclude that, under steel-making conditions, no large area inside an open-hearth chamber can be much cooler than the remainder of the chamber, excepting, perhaps, the surfaces of scarp during the melting period, when the charge is rapidly absorbing heat radiated from flame and walls. For example: the absolute minimum temperature in the bath in the finishing period is fixed at about 2,675 to 2,725 deg. by the melting point of the steel. The roof surface must be maintained at or above this temperature range to maintain sufficient heat flow into the bath. If the roof and wall surfaces are cooler than the bath surface, the latter will tend

to cool off by radiation of its excess heat to the roof arch and walls.

As the bath and walls tend to approach so closely to a uniform temperature during the working and finishing periods, the melting chamber may be considered to have a critical range of working temperatures during this period. The lower limit of this range is fixed at around 2,725 deg. by the melting point of steel. The upper limit is fixed by the minimum softening temperature of the recrystallized silica roof brick. This limit may be as high as 3,050 deg. in some cases, especially in roofs of acid furnaces, but may usually be placed at 2,975 to 3,000 deg. If the bath is heated much above this range, even a very thin roof arch is likely to be badly damaged by fusion of the brick.

The rate of steel production largely depends upon the amount of high-temperature heat supplied to the bath at intensities above the lower critical temperature (about 2,725 deg.). Suppose, for example, that a furnace is operated with such high heat losses and such a small supply of high-temperature heat that the roof arch can not be raised above about 2,725 deg. Such a furnace might be operated almost indefinitely without producing a single ton of finished steel. Some furnaces almost approximate this condition near the end of a long campaign. The roof arch, side walls, and port-end walls have been worn down very thin so that heat losses are very large. The checker chambers have become so clogged that the maximum draft available will not pull much air into the furnace. Such a furnace operates so slowly that a shut-down becomes inevitable.

The curves of Fig. 11 represent approximately the average surface temperatures of different areas in the melting chamber during a typical heat; the critical range as just indicated is shown by the horizontal dotted lines. The roof may be considerably hotter than the surfaces of rapidly melting charge early in the heat, but this difference becomes small as soon as the charge is melted and usually decreases to zero near the end of the heat. Occasionally the slag surface becomes slightly hotter than the roof surface at this period.

The slag layer is a poor conductor of heat, and if the bath was dead and the slag lay quiet on the steel its surface would usually be as hot or hotter than the roof surface. The stirring action of gases evolved from the bath, however, causes an increased rate of heat flow through the slag layer by convection, keeping the slag surface cooler than the roof until the bath as a whole approaches furnace temperatures. This cooler slag surface is the most important factor in protecting the roof from overheating by its rapid absorption of excess heat radiated down from the roof surface. Whenever a bath is killed so that the slag lies dead, its surface acts like a mirror which reflects nearly all the heat received from the flame back

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§For example, see Shack, A., and Rummel, K., "Die Anwendung des Gesetzes des Wärmeübergangs und der Wärmestrahlung auf die Praxis. Berichte der Fachausschüsse des Vereins Deutscher Eisenhüttenleute, Mitteilungen der Warmestelle, Nr. 51, Aug. 1923.



to roof and walls and transmits relatively little of the heat to the steel below. Such conditions always cause danger of overheating the roof. The same danger is present near the end of every heat when the bath is up to temperature and there is no cool surface to absorb excess radiant energy. During the melting period the cooler charge absorbs radiation rapidly and makes it very difficult to overheat roof or walls.

### Glazing of Roof Arch

Many open-hearth operators believe that a well-glazed roof surface is more resistant to overheating than the rough, porous surface of a new roof. This effect may be largely due to the fact that a well-glazed brick can reflect a larger percentage of the intense radiant heat received from the flame down to cooler slag or charge surfaces.

### Local Overheating and Hole Formation in Roof Arch and Walls

If the melting chamber is heated above the "critical range," fusion of the silica brick will occur even in the best designed furnace, where the flame zone is kept well away from all roof or port surfaces. This

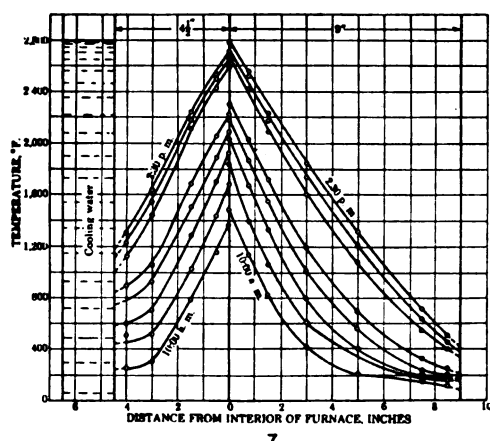


FIG. 7—Temperature gradients through 9 in. silica wall and  $4\frac{1}{2}$  in. silica water-cooled wall.

effect usually takes the form of a slow dripping or "sweating" action over the whole roof surface. In many furnaces, however, certain small areas in the roof or port arches burn out fairly regularly and form holes which often have to be patched while the remainder of the arch is in good condition. Obviously, in such cases, local overheating occurs in spite of the effect of radiation interchange tending to preserve uniformity of temperature throughout the furnace chamber.

In such cases the cause is usually an impinging current or eddy of hot gases from the flame zone on certain areas of an arch or wall surface. The result is really an excess amount of heat supplied by convection to one small portion of a surface, all of which is absorbing a nearly uniform supply of radiant heat. A factor which may be involved here is the tendency for a well-glazed roof surface to reflect a large part of an added supply of radiant heat, while an excess supply by convection transfer from hot gases impinging on the roof must be nearly all absorbed, whether the brick are glazed or not. An irregularity or an improper angle in the gas port arch, a poorly designed or dirty oil or tar burner, or a high pile of scrap on the hearth will result in an upward eddy of heated gases

from the flame toward the roof arch, usually near the incoming end of the furnace. In such cases it is common to find "holes" near one or both ends of the roof or along the arch near the skewback above the back wall, caused by overheating and fusion of the brick in these areas, which may have to be patched from one to three times during the life of a roof. When a whole roof arch is raised to 2,925 or 2,950 deg by the normal interchange of radiant heat from flame and bath, then a relatively small additional supply of heat by convection to a localized area should be sufficient to heat the brick to 3,000 deg., or above, and so cause fusion.

### Water-Cooling of Refractory Walls

The curves of Figs. 7, 9 and 10 indicate surprisingly high temperatures at the outside surfaces adjacent to the thin sheet iron water-cooling tank, which was held tightly against the wall surface as indicated in Fig. 12. Comparison with air-cooled walls of the same thickness indicates that water-cooling in this manner was no more effective than air-cooling in lowering the outer surface temperatures. These temperatures are obtained by extrapolation through  $\frac{1}{2}$  inch of brick and are only approximately accurate. Even after allowing for the possible error from this cause, however, we are forced to conclude that a large temperature drop must exist through the film between brick and water-cooler surface.

These results check with observed effects in water-cooled zones of walls or ports in regular furnaces, where a brick layer in front of a water-cooler is usually corroded until the water-cooler is exposed inside the furnace, when a thin layer of slag or dust usually deposits on its surface. Such conditions indicate the presence of a gas film between brick and water-cooler surfaces, with a large temperature drop across this film. The brick probably dissipates its heat largely by radiation, and the water-cooler surface is but little more effective in absorbing this radiation than the room temperature surfaces which receive radiation from an air-cooled wall. If perfect contact existed between brick and water-cooler surfaces, the cooling action would be much more effective, but in practice this condition is usually not even approached.

We may conclude that: (1) Refractories in a wall section backed up by a water-cooler are not "protected" by the cooler much more than to the extent of effect that air-cooling and free radiation would have on the same wall; (2) the essential effect of a water-cooler is simply to form an indestructible section which tends to stabilize and prevent collapse of the wall and has a small effect in protecting the brick adjacent to it from deterioration; (3) this result is obtained at the cost of a large loss of high-temperature heat which is absorbed by the water-cooler, with a further drop in furnace efficiency.

In general, water-cooling in the open hearth should be regarded as bad practice, as an evil which may in certain cases be made necessary by the limitations of available refractories or of the human element in the control of furnace temperatures.

At this point it may be well to compare the open hearth with the boiler furnace in relation to this question of water-cooling. The two furnaces are fundamentally different in that the boiler furnace really has no critical range of temperature such as those of the blast furnace or the open hearth which, to operate at all, must be given a certain amount of high-tem-

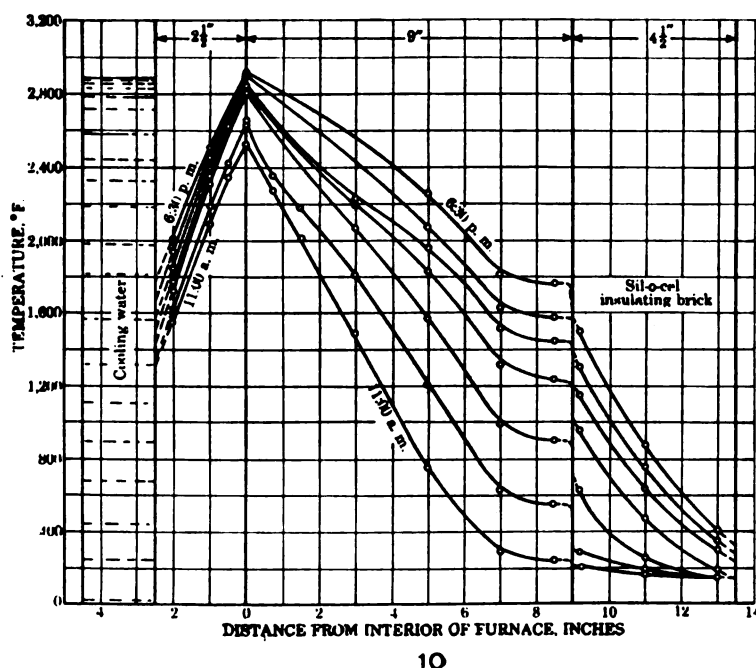
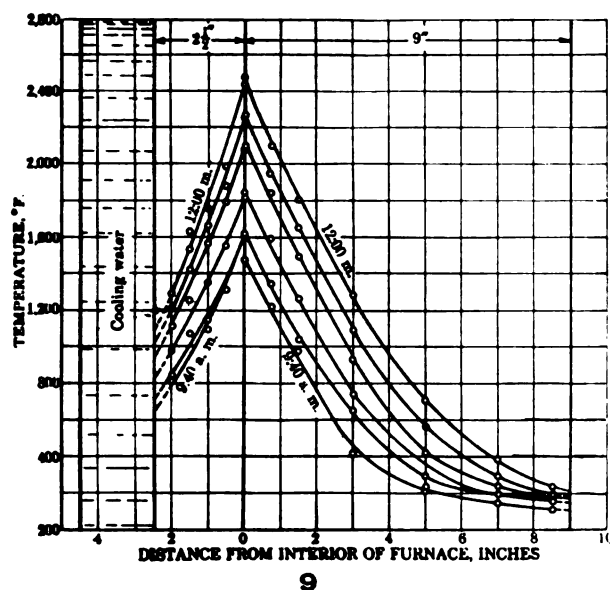


FIG. 9—Temperature gradients through 9 in. silica wall and  $2\frac{1}{2}$  in. water-cooled silica wall. FIG. 10—Temperature gradients through 9 in. silica wall insulated by  $4\frac{1}{2}$  in. insulating wall and  $2\frac{1}{2}$  water-cooled silica wall.

perature heat, or heat supplied above a certain intensity. In the boiler furnace all of the heat is available for use from the combustion temperature in the fuel-burned down nearly to the temperature of the feed-water heater, an average range of 2,800 deg. to 200 deg. Also, the essential business of the boiler is to heat up water and make steam so that part of the boiler tubes can be placed around inside the combustion chamber to increase boiler efficiency and at the same time give some protecting effect on the refractory walls behind these tubes.

#### Insulation of Walls and Deteriorating Effects on Refractories

The important causes of failure or deterioration of refractories in the open hearth are: (1) Surface corrosion by fluxes, (2) simple overheating and fusion, and (3) spalling. The spalling of refractories should be reduced to some small extent at least by insulation of the walls. Wide fluctuations in temperature should be much reduced and there would be flatter temperature gradient curves and more uniform heating of refractories.

Because of flatter temperature gradients, a given amount of overheating above its fusing point will do much more damage to a thick, insulated wall than to a thin, air-cooled wall. At a given inner surface temperature (above the softening range), the layer of softened brick substance is thicker, the better the insulation. Fusion would therefore be a much more important cause of failure in an insulated furnace. In fact, the successful use of an insulated roof arch of silica brick would probably entirely depend upon such accurate control of furnace temperatures that the arch surface would never be heated appreciably above 2,950 deg.

The rate of surface corrosion of refractories probably would be reduced in a well-insulated, efficient furnace. Wall surface temperatures would be about the same as in an uninsulated furnace. There are good indications that the rate of fluxing corrosion of brick surfaces in the open hearth largely depends

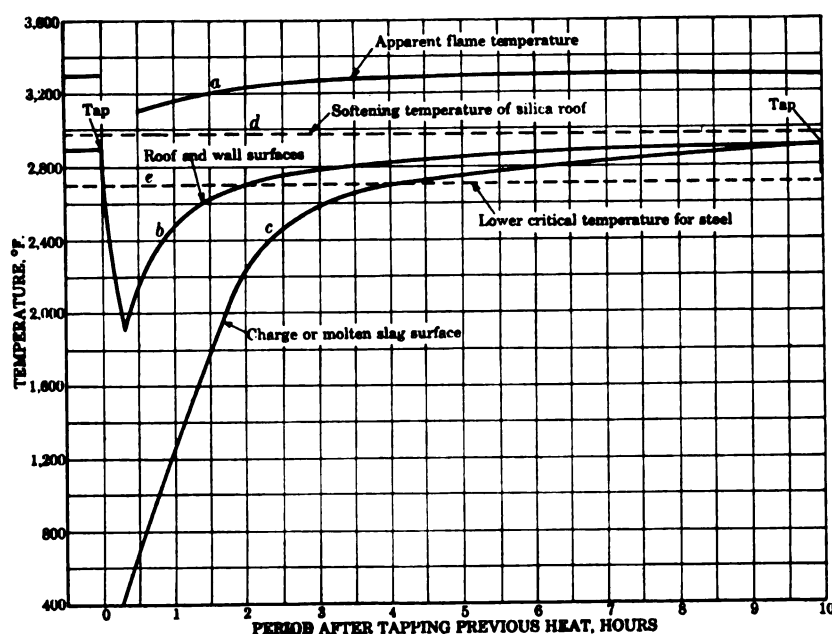
upon the rate with which finely divided flux particles are carried from the bath surface to various wall areas by the currents of gases. In a well-insulated furnace the volumes and velocities of these gases should be materially reduced, with a consequent reduction in the rates of wall corrosion. End walls should last longer, slag pockets would not fill so rapidly, and the rate of dust deposition in checker chambers should be reduced.

If refractories with effective melting points 200 deg. higher than the silica brick used for roof and port arches and sidewalls were available, the complete insulation of the open-hearth structure would be the obviously logical development in design. Even with the refractories available, however, we are forced to the conclusion that the failure of insulation is very largely a failure of furnace control.

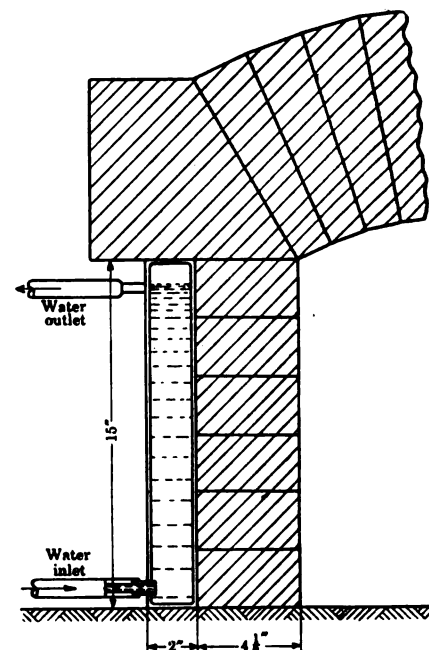
It should be feasible even in present furnaces to insulate checker chambers, tunnels, slag pockets, uptakes, and possibly the end walls and air port arches, although it would probably be necessary to have somewhat more careful regulation of flame combustion and temperatures in such furnaces. (Insulated checker chamber arches must be built of silica brick instead of firebrick to prevent danger of slumping under load). Insulation of the silica roof arch and side walls of the melting chamber could probably be made successful only by some accurate pyrometer method of controlling furnace temperatures, and does not seem at all likely to succeed under existing plant conditions. Insulated chrome brick walls might tend to slump under the load at high temperatures, which tendency is common in many other bodies.

A partly or completely insulated furnace would have to be operated quite differently to the present thin-walled, inefficient furnace. In the latter the rate of heat input does not vary much during the course of a heat because most of the fuel is burned to keep the furnace hot and only a very small part to melt and finish the charge. In a well-insulated furnace, heating could be rapid during the melting period, when the rapid heat absorption by the charge prevents





11



12

FIG. 11—Diagram showing approximate average surface temperatures in an open-hearth melting chamber during a heat.  
FIG. 12—Method of water cooling the wall.

overheating of walls. Near the end of the heat, however, the rate of heat input would have to be reduced to a very low value to prevent overheating.

Oxygen-enriched air should have more chance of success in an insulated and efficient furnace because the latter would use less fuel and therefore less oxygen. In general, the use of oxygen-enriched air and higher flame temperatures face much the same practical limitations as does the development of insulation. One bad feature of the use of small, very hot and concentrated flames might be their tendency to produce non-uniform heating in the furnace chamber, tending to overheat certain wall areas before radiation interchange could even up the temperatures throughout the furnace. Conditions for the successful application of special refractory bodies should also be more favorable in an efficient, insulated furnace, especially such bodies as would make possible the complete insulation of the whole structure.

### Summary and Conclusion

In general, the following principles seem to affect the relations between heat losses, temperature control, wear of brick, etc.:

1—Irrrespective of how much heat is lost through the walls of an open hearth, the inner surface temperatures must remain about the same to make possible a given rate of steel production.

2—Any additional heat losses through walls must be made up by additional heat input from the combustion of fuel. In general, therefore, the more inefficient a furnace becomes by heat losses through water-cooled and thin uninsulated walls the more rapid must be the rate of fuel input and the greater the volume and velocity of gases passing through the furnace system.

3—Inner wall and bath temperatures are controlled essentially from within the furnace. A roof arch, for example, is prevented from overheating by losing its excess heat by radiation down to a cooler bath, and

even a very thin air-cooled arch is never protected entirely from overheating by air-cooling from the outside. If the average interior temperature of the furnace rises above its softening range or if flame or hot gases impinge on one area of its inner surface, a roof arch will be overheated and fused regardless of how thin it is or how well it is cooled on the outside surface.

4—Except during the early melting periods, an open-hearth chamber cools and heats with close approximation to black body conditions. With a silica roof arch, such a chamber has a critical range of working temperatures at 2,725 to 2,975 deg.

5—With less insulation, thinner walls and better cooling on the outside, there is of course a more rapid drop in temperature gradients from inside to outside surfaces. Less heat is stored in the brick and heat flow is more rapid through the walls. This means that it is not only more difficult to overheat these walls from inside the furnace, but a given amount of overheating will form a thinner layer of softened brick substance and there will be less destruction of the wall in a given period. With walls of increasing thickness and more insulation there should be exactly opposite tendencies. A well-insulated wall will be more severely damaged by a certain period of overheating above its fusing point at the inside surface. The feasibility of insulation thus closely depends upon the accuracy of control of furnace temperatures, and of course this control becomes more and more important as furnace temperatures approach closer to the softening range of the refractories used in the furnace walls, which conditions obtains in the open-hearth furnace.

6—Water-coolers, as ordinarily used to protect certain portions of the furnace, have little effect on the refractory walls other than to furnish an equivalent substitute for conditions of air-cooling and free radiation. A wall section can be made permanent with a water-cooler only by exposing the latter inside the

(Continued on page 226)

# The Selection of Control Equipment

Attention is Directed to the Importance of Proper Starting and Regulating Apparatus. Use of Various Types as Applied to Different Kinds of Motors Explained

By GORDON FOX\*

**A**N effective motor drive is comprised of a suitable motor together with its proper control equipment. These two elements cannot be divorced and considered separately. The control is complementary to the motor. The motor type selected is often dictated by its susceptibility to suitable control. Not alone the separate elements but the combination must be correct to afford the best results.

The control may be either a minor or a major factor in a motor drive. In many cases the control functions merely as a device for starting and stopping the motor. It is then merely an adjunct to the motor. In most cases the control includes some features of motor manipulation or speed control or at least some protective features. In increasingly frequent instances the control includes automatic features or is especially adapted to a particular cycle of operations, governing the functioning of the driven machine through the intermediary of the motor. The motor responds to and translates the conditions imposed by the control. The control is then the major factor.

In the application of electric drive to any but the simplest uses, the question should always be raised as to the degree in which electric controllability can be employed to supersede mechanisms and to simplify the driven machine. Much recent improvement in industrial machine design has resulted from the adoption of the electrical viewpoint and the inclusion of the electrical equipment as an essential factor in machine performance.

As the choice between manual and magnetic control is influenced by many factors, a wide range of topics may receive consideration under this general heading.

Manual control is suited to the relatively simple applications or at least to the more common ones. The manual controller is less flexible in adaption to complex control features. It is essentially a standard product from which little variation is readily possible. The principle fields for manual controllers are: simple starters; straight reversing controls, machine tool starting, reversing speed control and braking functions; crane hoist and allied operations.

## Size of Motor

The size of motor plays an important part in determining whether manual or magnetic control should be used. The type of contacting devices ordinarily used for manual controllers are limited in current capacity, particularly in current rupturing capacity, due to sliding contacts and slow separation or breaking of contacting parts. The arcing which is necessarily associated with manual controls detracts from their reliability and increase the cost of maintenance. This effect is dependent to a large degree upon the amount of current handled. This, in turn, is dependent upon the size of motor and its voltage.

\*The Freyn Engineering Company.

Manual control is better suited to the control of small motors than large motors.

The nature of the service imposed upon the control equipment has an important bearing upon its determination. If a controller is called upon to function only infrequently, the maintenance cost will be small even though there may be appreciable arcing at each operation. A manual controller may be entirely feasible and satisfactory for service of occasional character while the same control would be unsatisfactory for severe service. Ordinarily it is not good economy to provide more elaborate or capable equipment than the service demands. If other factors do not enter, manual control may be considered, in general, as adapted to infrequent service. Magnetic controls, provided with quick-break contactors, magnetic blowouts and arc shields are better able to handle the frequent service tasks involving in excess of two or three starts per hour.

In many cases magnetic control is desirable because it provides a measure of automatic operation, thereby decreasing the demand for thought and care on the part of the operator. The driven machine, the motor and the control itself are generally better protected by magnetic than by manual control. Limit switches may be provided with magnetic control to check up on the operator and to safeguard against overtravel. Interlocking features may be introduced to insure proper sequence of operations or to safeguard men, machines, or motors. Because of the smaller master switch, the lesser manual work and mental demand, the operator does not fatigue so quickly when magnetic control is used.

Magnetic control is, or generally should be fool-proof in that the operators movements are simple and he is powerless to impose damaging conditions upon either mechanical or electrical equipment. Features necessary to this end are commonly incorporated in the control equipment. With manual control the operator governs the motor circuits directly. He is able to impose improper and severe demands upon the motor and with him lies the responsibility for the avoidance of this evil. For these reasons manual control may require more skillful operators.

Magnetic control, providing automatic acceleration can be adjusted to afford maximum speed of action consistent with mechanical and electrical limitations of the apparatus. To attempt equal speed with manual control quite definitely exposes the equipment to at least occasional excessive stresses.

Magnetic control is flexible in that devices and circuits can be devised to afford a wide range of action, indeed almost any cycle of operations within reason can be accomplished automatically through the intermediary of magnetic control. Moreover, additions or changes can be made subsequent to installation with comparative ease. Manual control is generally inflexible, permitting of little modification.



### Remote Control

The remote control nature of magnetic control may render it more convenient. The small master switch or push button station can be located to good advantage in a most convenient position and without forming an obstruction. Several control points may be supplied, located apart and as convenience may dictate. The point of control may be quite distant from the motor. The control panel itself can be located to best advantage independent of the master station, at a properly protected point and one affording a short and direct run of wiring between the feed and the motor.

Magnetic control, in general, is safer than manual control because the operator is exposed to pilot circuit voltage only, a factor of particular import in connection with high voltage installations. The main circuits are at some distance from the operator and he may be fully protected from possible arcing. Overload, undervoltage and other limiting and protective features may add further to the safety of a magnetic control installation.

In general, manual control is decidedly more simple than magnetic control. Magnetic control is becoming more generally understood and the trend is toward simplification. Much magnetic control is quite simple. But not a little is necessarily more or less complex. To function at its best it requires proper adjustment and intelligent attendance. While magnetic control demands less repairs, it demands a higher degree of skill in maintenance.

### Standard Versus Special Control

Manual control is inherently a fixed design permitting little leeway in detail specification by the user. Magnetic control, because of its assembled-unit character and because of its flexibility, permits of great variation in detail design, both with respect to scope of features included and also in the matter of alternative methods. The manufacturers of control equipment have developed certain standard assemblies. Quite naturally the use of these standard equipments is encouraged for as many applications as they can be possibly made to cover. Because of their fixed design and quantity production, standard control assemblies can be purchased more cheaply than special assemblies. It therefore behooves the user to adopt the standard designs wherever this can be done without undue sacrifice in the matter of suitability. Mediocre results often follow the attempt to apply standard assemblies for service to which they are not best adapted. Because special control assemblies require individual attention in negotiation, in design, and in production, the manufacturers are apt to attach extras and development charges for special features seemingly out of proportion to their apparent cost. Some of the larger users of magnetic control have found it advantageous, in some instances, to purchase the elements and assemble or modify the controllers themselves in order to avoid the overhead charges attached to the special features desired. Some control builders, however, seem to be in position to supply "made to order" assemblies with sufficient promptness and economy to render it entirely feasible, in fact, desirable for the user to obtain equipment thoroughly suited to his particular requirements rather than to confine himself too closely to "ready made" specifications.

Since magnetic controllers, standard or special, are comprised of standard parts, the special assembly involves little if any more protection in the way of repair elements than does the standard assembly.

The enclosure of control equipment is fast becoming almost universal. Local regulations in many cities have contributed to this practice. It is essential that small starters, master switches, drums or any apparatus handled by an operator or located about machinery be enclosed both for the safety of the operator, to minimize fire hazard and to protect the control itself. In the writers opinion the only control equipment which need not be enclosed is that which is installed in a power plant or some sort of substation or control room which may be kept reasonably clean and which is removed from manufacturing operations and traffic and accessible only to proper persons. The provision of such control rooms is often advisable.

Oil immersion of control equipment affords a number of advantages. Aside from increasing the rupturing capacity and increasing the capacity through heat dissipation it protects metal parts such as auxiliary contacts against corrosion, it lubricates bearings and moving parts and bathes the parts, keeping dirt out of air gaps, etc. Oil immersion of overload relays is particularly advantageous as it protects these important elements and maintains them in operative condition in the face of their infrequent movement. The principal disadvantage of oil immersion is the difficulty of inspection and access. This disadvantage is now minimized in the best designs.

### Selection of Direct Current Magnetic Control

It is almost impossible to sum up in a few paragraphs the fundamentals underlying the selection of magnetic controllers. Pre-requisites to the selection of proper equipment are, a full knowledge of all the functions and eccentricities of the driven machine and a knowledge of control elements and their action. If the purchaser of control apparatus is not qualified as a control expert he will do well to specify performance desired rather than controller details.

Among the factors which influence the control design, some of the more common may be mentioned:

Is rotation unidirectional; reversible or reversible?

Is speed-control or armature resistance points desired?

Are creeping speeds for set-up work desirable?

Is the motor a constant or adjustable speed type?

Is the motor shunt, compound or series wound?

Are any braking, slow-down or overhauling features involved?

Is operation occasional, intermittent or frequent?

Are brakes used? What is the relation to the control?

Are drift points desirable?

Has the drive exceptional inertia or other peculiarities?

What nature and extent of protection are needed?

Are limits or interlocking features required?

Location of control.

Cost and importance of the driven machine.

**Character of operators.**

Is it possible for unusual conditions to affect the load decidedly.

Safety features desirable.

**Selection of A.C. Control**

Many of the factors which influence the selection of d.c. control apply also to a.c. control. Because of its lesser flexibility a.c. control does not have quite such extensive ramifications of design. Aside from the factors listed, the electrical system, particularly the voltage, determines the type of control elements used.

The great majority of a.c. controllers are essentially starters for squirrel-cage induction motors or self-starting synchronous motors. These take the following forms:

Across the line starters.

Auto-starters or compensators.

Impedance starters.

Primary resistance starters.

Star-delta starters.

Multiple voltage switching.

These methods of starting are all in more or less common use. Across the line starters are standard for small induction motors and there is an evident trend toward the extension of this method to larger motors which are then particularly adapted in design to this form of starting, usually with a double cage winding.

The auto-starter or compensator, variously termed, has long been the accepted standard manual starter for squirrel-cage motors. This method of starting is also used extensively with magnetic control. It affords a minimum starting current from the line and permits the application of a definite reduced voltage at starting, subject to selection.

In the impedance starter, a relatively recent addition to the field, impedance coils are inserted in series in each phase to reduce the initial voltage. As the motor accelerates the voltage across the impedance decreases and the voltage applied to the motor correspondingly increases. Full voltage is finally applied to the motor by short circuiting the impedance coils. On light loads, low-voltage taps of auto-starters have a lower initial current inrush than the impedance starter, because of the transformer ratio. On more severe starting service this advantage decreases and the impedance method gains a measure of advantage due to the inherent voltage increase with the acceleration and the consequent ability to accelerate nearly to full speed before applying full voltage.

The fact that the transfer to full voltage is accomplished without opening the primary circuit is a further advantage of the primary impedance type of starter. Compactness, simplicity, and ease of repair are further characteristics of the impedance type of starter. This equipment lends itself well to oil immersion, which, in the writer's opinion is a material advantage.

The primary resistance starter is available both for manual and magnetic control. Its use is more common in the latter form. A popular type of manual control for motors of moderate size employs carbon disc resistors which are compressed to reduce the starting resistance, which is finally short circuited. Magnetic controls of the primary resistance type

more commonly use resistors of fixed value, although taps may be provided for selection. The resistance is short circuited in one or more steps.

Theoretically the primary resistance starter draws a higher starting current from the line than an auto-starter. This is particularly true where a voltage of 65 per cent or less is impressed in starting. Theory is somewhat upset by the fact that the current taken by a motor with an auto-starter at transition to full-voltage may be more than the starting current. This is particularly likely if a low starting voltage is used in which case the throw-over to full voltage may be necessary at a lower speed than if a higher starting voltage were used. In any event two disturbances are imposed, rather than one and the current intake is more fluctuating though of lesser magnitude. For the more severe cases, where 80 per cent voltage must be used in starting, the auto-starter has little if any advantage in line current intake. The primary resistance starter has the advantages of greater simplicity and ease of repair in addition to a gradually rising voltage during acceleration and no interruption of circuits during throw-over. The primary resistance starter tends to be bulky and expensive if the larger sizes of resistors of liberal dissipating capacity are used. Complete enclosure is of questionable advantage because of the restriction of heat dissipation. This type of equipment is not well adapted for oil immersion. The resistance starter is not suited for use above 550 volts.

The star-delta method of starting is rather uncommon, particularly for the larger motors. Its great drawback is the limited starting torque afforded. Standard manual controllers are available using this method. Special motor connections are necessary, involving six motor leads.

Multiple voltage switching is feasible in special instances where taps may be taken from transformers to provide reduced voltage for starting and where added complexity of wiring can be minimized. This method is sometimes used for small groups of large motors and for motor generators and synchronous converters.

**Control of Synchronous Motors**

The starting of synchronous motors was formerly done largely by manual switching. This method continues to be used for starting large synchronous apparatus particularly in stations where an attendant is required for other reasons. For the majority of industrial applications involving motors of moderate size, the recently developed magnetic or so called automatic starters are generally best suited.

In any case the question of full voltage versus reduced voltage starting must be considered. Several factors are involved. Sixty cycle motors at speeds up to 450 or 514 rpm. are commonly designed for full voltage starting. They will produce 35 to 50 per cent starting torque with 200 to 350 per cent of rated current input. Motors of higher speeds are available which will develop full load torque if started on full voltage but they will demand 400 to 700 per cent current input. Such an inrush may well be prohibitive. In the case of high speed synchronous motors the strains due to frequent starting on full voltage may injure the stator winding unless the coils are specially braced. Notably with high torque and high speed motors it may be desirable to start on reduced voltage to prevent shock upon the driven machine or the



mechanical transmission. Particularly with low speed drives of high inertia it may be desirable to start on full voltage to bring a machine up to speed in a reasonable time. Some low speed machines, such as compressors, may require full voltage starting in order to develop sufficient torque to break the machine away from rest.

### Rupturing Capacity

When a.c. current controllers are installed on systems where heavy currents will flow in case of short circuit, special provisions are sometimes necessary. Oil switches or other protective devices of ample rupturing capacity must be installed ahead of the controller and provision made to insure that, in case of

short circuit, the controller will not be called upon to interrupt the heavy current inrush. The overload device may well be arranged to open the feeder breaker and not the control contactors. In some cases selective time relays are used.

In some cases, in power plants, d.c. current coils are used on a.c. magnetic contactors to insure their holding in on short circuit.

### Costs of Controller Types

Because of the great diversity in control equipment it is only possible to indicate in a very general way the relative costs of a few representative controller types. This is attempted in Tables VI, VII, and VIII.

**TABLE VI—COSTS OF SOME STANDARD 230 VOLT D.C. CONTROLLERS**

| Motor horse power | Enclosed face-plate starter* | Compound manual speed regulator† | Revising drum control<br>Drum-speed regulating resistors |          | Simple, time-element automatic starter without overload protection |
|-------------------|------------------------------|----------------------------------|----------------------------------------------------------|----------|--------------------------------------------------------------------|
| 5                 | \$ 11.40                     | \$ 76.00                         | \$ 41.50                                                 | \$ 32.00 | \$ 34.40                                                           |
| 10                | 18.60                        | 106.00                           | 79.00                                                    | 39.00    | 62.50                                                              |
| 15                | 22.50                        | 116.00                           | 79.00                                                    | 49.00    | 72.00                                                              |
| 25                | 83.50                        | .....                            | 140.00                                                   | 71.25    | 125.00                                                             |
| 50                | 117.00                       | .....                            | 205.00                                                   | 140.00   | 220.00                                                             |
| 75                | 167.00                       | .....                            | .....                                                    | .....    | 395.00                                                             |
| 100               | 205.00                       | .....                            | .....                                                    | .....    | 425.00                                                             |

\*Multiple switch type on sizes above 20 hp.

†Face plate type with armature and field control points, enclosed.

Prices by courtesy of Cutler Hammer Manufacturing Company. February, 1927.

**TABLE VII—COSTS OF SOME STANDARD STARTERS FOR SQUIRREL-CAGE INDUCTION MOTORS**

Prices given are for 3 phase, 60 cycle, 440 volt equipment. Other low voltages and frequencies are generally similar in price, notably in smaller sizes

| Motor horse power | Manual                                          |                   | Magnetic                               |                                                       |                                                      |                                         |
|-------------------|-------------------------------------------------|-------------------|----------------------------------------|-------------------------------------------------------|------------------------------------------------------|-----------------------------------------|
|                   | Primary resistance with compression resistance* | Auto transformer† | Across the line with thermal overload‡ | Primary resistance with thermal and instant overload§ | Primary impedance with thermal and instant overload§ | Auto transformer with thermal overload‡ |
| 5                 | \$ 66.00                                        | \$ 76.00          | \$ 24.00                               | \$130.00                                              | \$152.00                                             | \$147.00                                |
| 10                | 69.00                                           | 76.00             | 27.00                                  | 139.00                                                | 162.00                                               | 147.00                                  |
| 15                | 74.00                                           | 76.00             | 27.00                                  | 157.00                                                | 166.00                                               | 147.00                                  |
| 25                | 78.00                                           | 78.00             | 39.00                                  | 182.00                                                | 193.00                                               | 160.00                                  |
| 40                | 88.00                                           | 88.00             | 39.00                                  | 260.00                                                | 256.50                                               | 168.00                                  |
| 50                | 88.00                                           | 88.00             | 39.00                                  | 296.00                                                | 266.00                                               | 168.00                                  |
| 75                | 140.00                                          | 155.00            | 107.00                                 | 410.00                                                | 301.00                                               | 470.00                                  |
| 100               | 145.00                                          | 155.00            | .....                                  | 420.00                                                | 378.00                                               | 470.00                                  |

\*Prices by courtesy of Allen Bradley Company.

†Prices by courtesy of General Electric Company.

‡Prices by courtesy of Cutler Hammer Manufacturing Company.

§Prices by courtesy of Rowan Controller Company.

**TABLE VIII—COSTS OF SOME STANDARD STARTERS OF WOUND-ROTOR INDUCTION MOTORS**

Prices given are for 3 phase, 60 cycle, 440 volt equipment. Other low voltages and frequencies are generally similar in price. Prices depend on secondary current. Prices shown are approximate.

| Motor<br>horse power | Drum type                    |                                                      |               |                 | Magnetic                                                                |
|----------------------|------------------------------|------------------------------------------------------|---------------|-----------------|-------------------------------------------------------------------------|
|                      | Drum only                    |                                                      | Resistors     |                 | Primary and secondary<br>enclosed panel Resistors<br>for heavy starting |
|                      | Secondary only,<br>reversing | Non-<br>Combined primary and<br>secondary. Reversing | Starting duty | Regulating duty |                                                                         |
| 10                   | \$ 64.00                     | \$ 80.00                                             | \$ 17.00      | \$ 20.00        | \$110.00                                                                |
| 25                   | 64.00                        | 102.00                                               | 17.00         | 52.00           | 153.00                                                                  |
| 50                   | 64.00                        | 102.00                                               | 28.00         | 81.00           | 184.00                                                                  |
| 75                   | 64.00                        | 102.00                                               | 35.00         | 164.00          | 340.00                                                                  |
| 100                  | 113.00                       | 140.00                                               | 35.00         | 205.00          | 390.00                                                                  |
| 150                  | 113.00                       | 140.00                                               | 69.00         | 325.00          | 500.00                                                                  |
| 200                  | 160.00                       | 280.00                                               | 69.00         | 405.00          | 650.00                                                                  |

Table VI shows costs of 230 volt d.c. starters and simple controls. The second column gives prices of enclosed face-plate manual starters in 5, 10 and 15 hp. sizes and enclosed multiple-switch starters in larger sizes. The compound speed regulators listed in the third column are of the face-plate type with both armature-control and field-control speed points. The drum control is for simple reversing duty, the resistors listed being suitable for average speed-regulating service. The magnetic starters listed are simple enclosed type, with line contactors provided on ratings of 10 hp. and above.

Table VII shows costs of several types of starting equipment for squirrel-cage induction motors. All prices refer to enclosed starters provided with overload protection. Prices are given for 440 volt equipment. In many instances the prices for other low voltages are the same or similar but there are many exceptions. It is of interest to note that, for the smaller size motors, d.c. starters are appreciably cheaper than a.c. starters (excepting across-the-line types). In the larger sizes the costs are similar.

Table VIII shows costs of drum-type control for wound-rotor induction motors with resistors for start-

ing duty or for speed-regulating duty. Where speed regulation is involved the cost of the resistors is a primary factor which renders this type of speed-control installation rather expensive. This table also shows costs of magnetic-control handling both primary and secondary circuits for starting duty. Because of the dependence of control cost on secondary voltage and current valves, which are subject to variation, the prices shown are rather approximate.

All control prices shown are "book" or "net retail" prices as of February, 1927. All controllers listed in these tables are standard. As previously intimated, special controllers involve cost considerations affecting each case individually.

The above remarks concerning controllers and their selection, are necessarily brief and general in character and refer to control equipments as a whole. More specific discussion of definite control types and the individual elements entering into the make-up of controllers, will be found in the companion volume "Principles of Electric Motors and Control." The selection of controllers for specific apparatus is treated in subsequent chapters in this volume.

## Open Hearth Furnace, Past and Present

A Practical Furnace Operator Reviews the Development to the Present Day—Manner of Constructing a Modern Furnace Described—Operating Features Mentioned

By CHARLES S. NUGENT

**I**N the year 1722, a French scientist by the name of Reaumur conceived the idea of making steel on the breast of an open hearth furnace by an admixture of cast iron and wrought iron. Although the French government encouraged this new idea, it did not prove successful.

The next experiment was conducted by C. W. Siemens, in the year 1861, and later others were carried on in a very small way by one or two of his licensees.

Messrs. Pierre and Emil Martin of the Sieuill works, near Paris, were the first to bring this new process to a commercial success. This was in the year 1864. Speaking of this furnace, C. W. Siemens, in a paper read before the Chemical Society, May 7, 1868, said: "It was chiefly intended for a heating furnace, but was so constructed of Dinas silica brick and of such form that it could be used for either purpose melting or heating."

The furnace was a crude affair, built much like a heating furnace of today, with the same kind of regenerators, only they were set under the furnace. The air regenerator was on the inside and the gas on the outer, while the uptake was constructed to run up the center of the chamber to the inlet of the port. The fame of this new process soon spread all over Europe and the United States. Mr. Hewitt, of the firm of Cooper & Hewitt Company, of Ironton, N. J., who had secured a license for all rights in the United States, built a 5-ton furnace, but it did not operate successfully and in a year or so was discontinued.

The Bay State Iron Works of South Boston, which had been manufacturing iron rails, were the next to

attempt the manufacture of the Cooper-Hewitt Company. This company built larger gas producers and made a radical change in the construction of the furnace besides providing ample regeneration by enlarging the gas and air chambers. Drawings showing the alterations were submitted to Mr. Siemens, who declined to furnish any information, but nevertheless the furnace was erected. Thus, we find the first American design of furnace a great success. This furnace, with a much deeper bath, a shell lined with silica brick, stepped up sides and ends, made the work of making the bottom and banks comparatively easy. It had a gas port and worked clean and fast, producing a very high grade of steel in comparatively large quantities. Operation began in the year 1870 and was so successful that in the following year the Nashua Iron Company, Nashua, N. H., and Messrs. Singer, Nimick & Company of Pittsburgh each built a furnace. These furnaces were started in 1872 and worked well, making a high quality of steel. The next year, the Otis Steel Company of Cleveland, Ohio, erected a furnace, and in 1874 it was placed in operation.

By this time many mechanical features had been developed and these were of material assistance in plant operation. A hydraulic crane was installed and with this the ladle could be lifted and swung under a spout so that when the steel was in the ladle it could be moved over the pit, which was of horse-shoe design. This eliminated the horse-shoe design on the breast of the furnace, in which, up to this time, the nozzle and stoppers were set. The "Eighties" were important years, for up to that time it was considered an axiom that phosphorus could not be removed from



steel at high temperature, but the inventions of Snelus and Thomas demonstrated that this could be accomplished. The Otis Steel Company was the first to make basic steel in the year 1885.

### Present Day Construction

In the construction of an open hearth furnace, we must consider the ratio of width to length, and the ratio of depth to length. These ratios will determine the capacity of the furnace and by selecting a ratio of air to gas, the size of the chamber is determined. In a plant of 14 furnaces, there must be at least two furnaces that will differ from the rest. These must have two big doors in order to handle big pit scrap and overflows from the steel ladle called "chocolate" drops. The writer will try to outline one of the furnaces. The pan is set and two layers of clay brick are placed on the bottom, then a  $4\frac{1}{2}$ -in. layer of magnesite brick is laid to within 3 ft. of the tapping hole. Here we drop  $2\frac{1}{2}$  in. and place another layer. This will give us 5 in. more magnesite in front of the hole. The bottom when completed will be 15 ft. wide and the length 43 ft., while the depth will be 2 ft. 6 in. The furnace length over all is 73 ft., the door sills are 2 ft. 4 in. from floor level, and the skew back channels are 5 ft. 2 in. from the sill plate. Now we must turn to the gas ports. In order to offset the amount of air that is drawn into the furnace under and around the five doors, we must set the "windows" of the port 4 in. to the front of the center line of the furnace and bring the back wing 4 in. further ahead or to the tapping hole. The port is the new long wing kind. This enables us to force the air down and form a rapid and short combustion about 4 ft. from the port. After the brick masons have finished the slopes, which drop about  $1\frac{1}{2}$  in. to the foot, a form is put in behind the line of the port and 2,000 lb. of good silica sand with 2 per cent lime spread on the masonry. This lime is added to fuse the sand. A mixture of 2,000 lb. of chrome and magnesite in the ratio of 3 of magnesite to 2 of chrome ore is also laid. When complete the bottom of the air port is just 6 in. below the port arch. Furnaces built this way are fast working and last a long time. Heats are made in  $6\frac{1}{2}$  hours and the steel is of highest quality. The side walls are blocked in to the port lines to 54 in. on the back and 48 in. on the front. The air uptakes are 42 x 42 in. and the gas uptakes should be made no larger than would warrant a free flow of gas as the uptake will soon get big enough.

### Flues and Gas Producers

The flues should be as large as possible as this will eliminate four or five burnouts a year. If we make them 5 ft. wide and 9 ft. deep, we can run two or three days longer at a time. At the end of the first year, enough will be saved to pay a great part of the total construction.

It is well to consider the gas producers with self-feeding, self-poking device, self ash-removing and mechanical scrapers. This in itself guarantees ample supply of good gas with no lost time cleaning fires and no breaking of the zones which add so much to the value of the product. There has been quite a lot of trouble with the "down take" of the air chamber when built too close to the bridge wall, for when built this way it causes "scars" in the wall and slag in the checker chambers, incurring loss in operation and no recovery of the checkers after the run or life

of the furnace. This is eliminated by setting the bridge wall 3 ft. into the chamber, providing more space for slag in the pockets. It is difficult to tell how much water should be used on a furnace. A strip of low carbon steel laid between each row of brick extending  $2\frac{1}{2}$  in. over the wall in the port will melt, forming an oxide, and will prolong the life of the brick.

A by-pass must be placed between valves and the stack. This will enable the dampers to be lowered while burning the soot out of the flues. As there is no soot between the checkers, then there is nothing in the regenerators to burn, hence the dampers can be put down and the by-pass that connects the gas flue to the main stack may be used. This can be done by the erection of a goose-neck, one side in the gas flue and the other in the stack flue. Now the doors are opened and the sediment ignites and burns. When the gas-makers have the main burned out the gas sewer is clean and the slides and the doors can be closed. This will reduce the lost time 30 minutes, to the burnout, which means much as the furnace may be charged with a soaker, the scrap red hot, and instead of a long line from gas to tapping, the heat melts in less than regular time, this means  $1\frac{1}{2}$  hours per burn-out.

The Towne Scientific School of the University of Pennsylvania announces a course in Fuel Engineering opening September 30, 1927. Among the subjects embraced in the course are the following: Fuel Resources; Mining Methods; Composition and Combustion of Fuels; Furnaces; Fuel Testing and Sampling; Research. Students desiring to enroll should apply to Dean John Frazer, Towne Scientific School, University of Pennsylvania, Philadelphia, Pa.

### Factors Affecting Open-Hearth Refractories

(Continued from page 220)

furnace, which entails a large loss of high-temperature heat by radiation to this cool surface.

7—With better insulation of the structure, the wear of brick by spalling should be somewhat reduced, the rates of fluxing corrosion of brick and of filling of slag pockets and checkers should be lessened, but the tendency of overheating the furnace and of fusing or softening the refractories under load would be increased. In general, the necessity for careful temperature control would increase in direct proportion to the amount of insulation used on an open-hearth structure.

The present discussion obviously gives only a rough qualitative picture of certain problems which are badly in need of more definite quantitative treatment. The difficulty here is that data are almost entirely lacking on the various heat transfer coefficients at high temperatures. Radiation coefficients for glazed and rough brick surfaces are almost all undetermined, also the various film resistances to convection and conduction heat flow in gases at high temperatures. Conductivity coefficients for various refractories have been determined with fair accuracy at lower temperatures, but there are indications that in the higher ranges the true conductivities of many brick bodies are considerably higher than those indicated by the published data. This paper may have some practical value, however, in helping to form a fairly accurate picture of certain controlling factors in operating open-hearth furnaces.

# Progress by Reason of Electricity\*

An Outline of Developments in Our Industries Made Possible by  
the Use of Electricity. The Electric Magnet Has  
Been of Service Especially in Steel Works

By F. W. JESSOP†

**I**N 1876 the wonder of the Centennial Exposition was a 500-hp. engine generator. In 1902 the Yerkes Order for a 5,000-hp. turbine generator set was considered revolutionary but recently the General Electric Company has accepted an order for a turbine generator set of 280,000 hp. and efficiency in the use of coal or water power has grown with the increase in size of units so that a ½ lb. of coal will now do the work for which 10 lb. of coal was formerly required.

The location of power plants at the mines has often been advocated, but this has proven impractical because several tons of water are required per ton of coal used so that you will find the larger power plants now located beside large bodies of water.

Electric power has revolutionized the design of blast furnaces which are now equipped with motor driven turbo blowers, revolving tops for properly distributing the burden, electric skip hoists for raising the coke, limestone and ore, motor driven car dumpers, ore bridges, larry cars, pig casting machines and usually an electric locomotive for shifting cars. The beehive coke oven at the mines saves nothing but the coke itself so now the coal is transmitted to the furnace plant where electrically operated ovens make and save all of the by-products. The gas from these ovens and from the furnace itself is turned into electric power and there usually being a large excess over what can be used to advantage in the plant, this power is connected to the super-power transmission lines with switches and meters in both directions so that the furnace plant can be fed with power from the distribution system when necessary, but usually the blast furnace plant is feeding power to the transmission system and in addition to this extra gas may be fed to the local gas company.

To realize all of this economy requires that such a blast furnace plant must be run continuously and the pig iron for which it was originally built has, therefore, become a by-product and must be stored if it cannot be sold immediately. Therefore, great storage yards with enormous cranes and large lifting magnets become an integral part of the system and all of these developments are tending to equalize production, employment and business prosperity, leveling to a great extent the previous peaks and valleys of prosperity and dull times.

## Steel Mills Motor Driven

Steel mills are no longer vastly expanding their electric power stations and many such plants have been abandoned although steel mills are almost entirely motor driven, motors being used to drive not only rolling mills themselves, but now being developed and used for driving the individual rolls in the tables as well as all of the auxiliary machinery and

for these purposes power is usually bought or at least available in case of a shut down or trouble in the steel mill power plant.

One of the great advantages besides an unfailing supply of power is that this outside power can be transformed at each location to what ever form a.c. or d.c. in which it can be used to best advantage. Steel rolling mills are now so universally driven by electric motors that when recently several mills were equipped with steam engines the installation was carefully studied and tested and became the subject of a special meeting and discussion held by the Iron & Steel Electrical Engineers in Pittsburgh. Special local conditions influenced the choice of motive power in this particular case but the relative economy could not be accurately determined because sufficient time had not yet elapsed.

Electric furnaces sometimes used for making castings, but usually used for making tool steel are spreading throughout the country as low priced power becomes available. Such furnaces are so exactly controlled that uniform high grade product is assured.

In 1896 the writer worked at Homestead Steel Works and at that time over 400 men were required to operate an open hearth plant having seven furnaces. About that time electric overhead cranes were installed for handling the pig iron and scrap in the stock yard and electric operated charging machines were installed in the plant so that the number of men about that plant was reduced to about 50. In 1905 a lifting magnet was developed which would satisfactorily and economically handle pig iron and scrap materials with the result that most of the labor was eliminated from the stock yard and today an open hearth plant is almost lonely because of the very few men required to operate it. In fact, there would not be enough men available to produce and roll the steel, now used, by the old manual labor methods.

Recently by the use of all asbestos insulating material lifting magnets have been developed which will handle steel up to about 1,450 deg. F. or just under what is known as the critical point above which steel is not magnetic and cannot be lifted. This process saves many hours in transferring steel from one process to the next and of course also saves much gas or oil required to re-heat the steel for the next process.

## Electric Welding

During recent years tremendous progress has been made in the art of electric welding.

A system of piping 90 miles long and 5 ft. in diameter was required in California. It was to be made from plates 8½ ft. wide, 30 ft. long and from ¾ to ¾ in. thick and, therefore, had to be made in the East, but to transmit such piping after fabrication would require a car per section and would be entirely out of the question. The contract for the plates properly machined was given to Newport News who used 24

\*Extracts from speech delivered before The "Big Ten" Club of Cleveland.

†President, The Ohio Electric and Controller Company, Cleveland, O.



small magnets in groups of four each on a spreader beam to handle the plates.

The plate was lifted out of the car with the hoist operator riding on it, transferred to an enormous shear installed at an angle of 45 deg. and the ends sheared, then onto a plate planer where one edge was machined, from there to a second planer where the other edge was machined and then onto a car which delivered it to a ship and the whole lot transferred to California where each plate was bent to a half circle, electrically welded and the sections also welded to one another. These processes resulted in quick work at a minimum of labor and, therefore, low cost. An interesting point is that the trench for this piping was dug only deep enough so that it could be covered and protected from the sun. In the valleys where pressure was high the  $\frac{3}{4}$  in thickness was used and over the tops of the hills where pressure was at a minimum the  $\frac{3}{8}$  in. thickness was used.

The arc welding process is used for making electric joints, for welding all sorts of tanks and boilers and now has been developed to a point where it is also used for welding the various structural members of large buildings and recently Westinghouse Company built a five-story factory building 80 ft. high by 200 ft. long by 70 ft. wide, electrically welding all of the joints.

No rivets were used and the weight of steel in the building was 700 tons, whereas, it would have required about 800 tons of steel had the members been riveted. Recently a new Coast Guard Cutter for use in the dangerous work among the ice floes of the north was almost entirely a welded job.

#### Railroads Electrified

The railroads have long recognized the economies of electric power, but in recent years its application to their various problems has rapidly expanded. Long tunnels were almost impossible of operation with smoke producing steam locomotives, but electric locomotives solved that problem. The capacity of many railroads over the mountainous divisions was very limited with steam locomotives which must operate at considerable speed to produce their maximum power but with the use of electric locomotives driven by series motors maximum power may be developed at low speeds and the capacity of some lines in mountainous districts has been trebled and quadrupled by the use of electric locomotives.

Railroad shops maintain very elaborate and complete machine equipment much of which necessarily stands idle for considerable periods and most of this is now driven by individual motors which cost considerable money but costs nothing for operation unless the machine is actually being used, whereas, with the old belt and line shaft system it took almost the same power to run the whole shop with or without actual load on the machines.

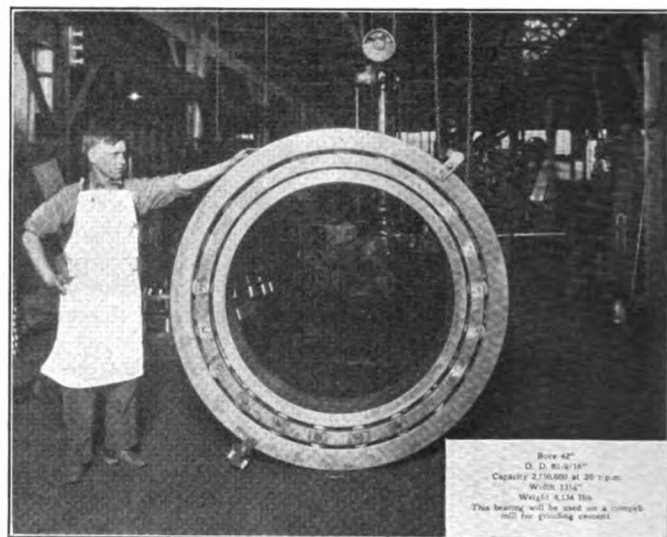
Manufacturing plants in general were among the first to utilize electric light, electric drive, electric heat and electric power for special purposes. An interesting example of the flexibility and possibilities of this form of drive is exemplified by a large profiling machine consisting of two work tables and two spindles, one table carries the block of steel or iron being worked upon by means of a milling cutter, the other table carries a model made of wood, plaster paris, lead, wax or other materials and over this model

travels a spindle carrying a small pointer. Feeds and speeds of these two spindles are driven by electric motors and they are synchronized so that the cutter moves in exact accordance with the pointer and every figure or form on the model is reproduced in the steel. This machine is said to be so accurate that if a hair is laid on the model it will be found to be reproduced in the steel. It would scarcely be possible to synchronize the control of these two spindles so accurately with any other form of drive.

#### The Largest Timken Bearing Ever Built

The largest bearings ever built by the Timken Roller Bearing Company have just been completed and shipped, according to officials of the company. These bearings have a bore of 42 in. and an outside diameter of 61-9/16 inches. At 30 r.p.m. these bearings have a capacity of 2,750,000 pounds. The weight of each bearing is more than two tons.

Not only are these bearings the largest ever built in the Timken plant, but they will be installed by the Allis-Chalmers Manufacturing Company in the largest



compex mill in the world. This will be put in service in a plant manufacturing Portland cement. This mill has a diameter of 10 ft. and 9 ft. by 45 ft. long and is used to take the clinker from the cement kiln and grinding it to finished cement in one machine.

The advantages of the Timken Bearing in this machine will be the material reduction of the overall length of the machine, since the width of the Timken Bearings is only 13 $\frac{3}{4}$  in. Likewise, Timken Bearings may be adequately enclosed, which will obviate the necessity of renewing the lubricant supply except at infrequent intervals. The tapered construction of the bearing permits the carrying of all loads, regardless of direction without the use of thrust plates or special thrust bearings.

Bearings of unusual size and large capacity have been built for sometime in the Timken plant and are used in many applications in steel mills, and other types of equipment where shafts of unusual size and loads of exceptional magnitude require bearings capable of withstanding the severe service for long periods without renewal.

# Low Temperature Carbonization of Coal\*

The Various Systems For Carrying On the Process Are Listed  
and the Operating Features, Which Differentiate Them,  
Are Described. Economies Make Process Attractive

By ROBERT M. CRAWFORD†

AS early as the year 1819 the question of the most economical temperature to be used for the coking of bituminous coal was a much disputed one in England—this question today is, over a century later, still a much disputed one wherever a coking industry has been established. Low temperature carbonization has, by its radical proponents, been acclaimed to be the ultimate solution of the problems of coal conservation and motor fuel supply; and, by its uncompromising opponents, it has on the other hand been condemned as a useless undertaking.

During the past few years the subject of low temperature carbonization has been given considerable cognizance and a confusion of processes have been projected and tried. The reinforcement of Germany's oil supply, the production of a clean, solid fuel for England's open grates, and the desire for a smokeless domestic fuel for America, have led to important commercial attempts. In Germany and England, because of economic conditions, the greatest success has been attained commercially in the low temperature field, while this country is just beginning to feel its way commercially. Although it cannot be said that low temperature carbonization in any country has reached a state of development such as to show that it is economically sound, endeavors within the next few years will undoubtedly find a proper place for the method in our economical system.

## Technical Requirements of Low Temperature Carbonization

The distillation of bituminous coal at any temperature below about 1200 deg. F. is generally conceded to mark such a process as one of low temperature carbonization. Without going deeply into the technical reasons for indicating this particular temperature, it is selected because, at and above this temperature the primary products of coal distillation undergo molecular re-arrangement to form products with which most of us are familiar as coming from the by-product coking of coal. These main primary products, gas and tar, yielded by low temperature carbonization are different from those yielded by high temperature carbonization. The gas has a much higher calorific value, sometimes equalling that of natural gas, while the tar resembles petroleum in many respects rather than what we call "coal tar" generated in the high temperature process.

Generally speaking, there is fundamentally required in any low temperature carbonization process the following:

1. Heating of a body of coal quickly and uniformly to coking temperature.
2. Speedy removal of distillation products in such a manner that they do not suffer an increase in temperature.

These requirements of a low temperature process are more simply stated than to carry out and the ingenuity of the engineer and designer is often taxed to the limit. Where coal is to be heated in thin layers to obtain rapid rise to the coking temperature, one is taxed with the problem of handling a small coke output per unit of retort volume; where a large body of coal is to be agitated over a heating surface to obtain quick and uniform rise to coking temperature, one is taxed with the problem of handling a sticky, plastic mass somewhere in the retort; where a large body of coal is to be heated with hot gases to coking temperature, one is confronted with dilution of distillation products with inert gases and with supplying comparatively large quantities of heat with a medium of low heat capacity; and so on.

The low temperature carbonization processes thus far developed, at least to the extent of commercial trial in a small way, may be classified roughly as follows:

### Class I

Processes utilizing indirect heating of coal:

A—Carbonization of a body of coal at rest in batches:

1. The Coalite process, English.
2. The Parr process, American.

B—Carbonization of a body of coal at rest in continuous fashion:

1. The Raffloer process, German.
2. The Piron process, American.

C—Carbonization of a body of coal in motion in continuous fashion:

1. The McIntire process, American.
2. The Greene-Laucks process, American.
3. The K. S. G. process, German.
4. The Thyssen process, German.
5. The Carbocite process, American.
6. The Lamie process, American.

### Class II

Processes utilizing direct heating of coal:

A—Carbonization of a body of coal in slow continuous motion:

1. The L & N process, English.
2. The Bussey process, American.
3. The McLaurin process, English.
4. The Doherty process, American.

B—Carbonization of a body of coal in fine state of subdivision in rapid, continuous motion:

1. The McEwen-Runge process, English-American.

To bring forward, now, in some specific manner what has been accomplished thus far in the low temperature carbonization of coal, it remains to describe briefly some of the above typical examples listed.

### The Coalite Process

In the Coalite process as operated at Barnesley, England, the coal is coked in batches in vertical, fire-

\*Paper read before Prime Movers Committee, N.E.L.A. Columbus. February 16, 1927.

†Engineer, McAleenan Corporation, Pittsburgh, Pa.



brick retorts measuring 9 ft. 6 in. high by 7 ft. 3 in. long at the top (7 ft. 6 in. long at the bottom to allow a taper to facilitate coke discharge) by 11 in. wide. The retorts are arranged in battery form with the necessary heating flues between retorts, the general arrangement being similar to the high temperature oven battery. Each retort contains a set of collapsible plates so arranged as to occupy about 5 in. of the width of the oven when expanded during coking. These plates, which are perforated to allow the distillation gases to pass from the coal freely, are expanded while charging the retort so that about 3 in. of coal thickness is presented to the heated walls of the retort. The coking temperature is about 500 deg. C and the coking time is about 8 hours.

At the end of the coking period the plates are collapsed and the hot coke is dropped through a specially constructed water cooled bottom door into a cooling chamber located below each retort. The cooling chambers are closed, water jacketed steel plate chambers in which the coke is allowed to cool before being discharged. The water used in the bottom doors and in the cooling chambers is used as boiler feed. (For a more detailed description the reader is referred to "Low Temperature Carbonization" by Wellington and Cooper, published by Charles Griffin and Company, London, England.)

The yields from this process are given as follows per ton of coal:

|                           |                              |
|---------------------------|------------------------------|
| Low Temperature Coke..... | 1400 lbs. (10 per cent vol.) |
| Low Temperature Tar ..... | 23 gal.                      |
| Gas .....                 | 5,200 cu. ft. (650 Btu.)     |
| Light Oil (from gas)..... | 2 gal.                       |

The tar and light oil, upon subsequent refining, yield a suitable motor fuel, but the amount is not stated.

#### The Parr Process

This process, developed by Prof. S. W. Parr at the University of Illinois, involves two steps, (1) preheating raw coal in a rotary kiln by direct contact with hot non-oxidizing gases, (2) final coking of the preheated coal in a vertical cast iron shaft heated externally to 1300 deg. F. The essential principle claimed is the utilization in the second step of auto-genous heating of the coal induced by exothermic reactions occurring in the carbonization of high oxygen coals.

#### The Piron Process

The Piron process developed by E. H. Piron and operated by the Ford Motor Company of Detroit and Canada may be described as follows:

The process makes use of heating coal in thin layers to coking temperature by feeding a one-half inch layer of crushed coal into pans which pass through a closed distillation chamber by floating on a bath of molten lead. The heat for coking the coal is derived by direct heat transfer from the lead bath through the metal pan and into the coal layer from the bottom only. The lead bath is contained in a pan built into the retort and is heated by flues carrying combustion gases and which are submerged in the lead bath. The coal conveyor passes slowly through the distillation chamber traversing its length of 40 ft. in four minutes during which time the coal is coked. The coke is discharged on to another conveyor located underneath in a separate chamber where it is quenched by steam. The two chambers are prevented

from communicating by the use of suitable shields. The temperature of distillation is 1200 deg. F.

The oven at Walkerville, Canada, which was the latest unit operated, was constructed having three conveyors, each 4 ft. wide entering the distillation chamber which was 40 ft. long. This unit gave good results and operated at the rate of 43 tons coal per day.

The following yields are given per ton coal:

|                            |                              |
|----------------------------|------------------------------|
| Low Temperature Coke.....  | 1460 lbs. (10 per cent vol.) |
| Low Temperature Tar.....   | 29 gal.                      |
| Gas .....                  | 4000 cu. ft. (750 Btu.)      |
| Ammonia .....              | 2 lbs.                       |
| Light Oil (from gas) ..... | 2 gal.                       |

All of the Ford installations were operated with the lead bath and extreme difficulty was experienced in keeping the lead confined. Later developments, now being included in an installation building in Italy, have done away with the lead bath, substituting therefore a conveyor of heavy iron plates which are preheated in a separate combustion chamber to 1200 deg. F., on to which the coal is charged as the plates enter the distillation chamber. The plates are of sufficient size as to deliver enough heat to a half-inch layer of coal distributed thereon to coke the coal in five minutes with a temperature drop of 2-300 deg. F. The cast iron plates are arranged in the form of a conveyor and are heated in a lower chamber to the proper temperature by direct combustion gases from a gas producer or stoker.

#### The McIntire Process

The McIntire process, as operated by the Consolidated Coal Products Company, Fairmont, W. Va., bearing the name of C. V. McIntire, its designer, is a modification of the first attempt at low temperature carbonization in this country by the one time International Coal Products Company, which operated the original "Carbocoal Process" at Clinchfield, Va. The process is a two-stage process, (1) a primary coking stage in which the coal is coked to a char and (2) a secondary stage in which the briquetted char is further heated. The process has for its purpose the making of an anthracite substitute from bituminous coal.

The primary retort consists of a horizontal steel plate cylinder having the bottom formed into V-shaped grooves—a longitudinal section through the retort would show the bottom to be like the folds of an accordion. An agitator shaft extends horizontally through the center of the retort and consists of a large steel pipe of heavy section on which are 13 radial steel paddles arranged in rows 90 deg. apart. An oscillating motion is imparted to the paddle shaft to sweep the paddles over the V-shaped heating grooves. This motion agitates the coal which enters at one end and causes it to be moved forward to be discharged at the other end. The retort is 8 ft. in diameter by 15 ft. long, is heated externally and has a capacity of 40 to 45 tons coal per day.

An important feature of the retort is a series of stationary wiping arms which are suspended from the cover and so arranged that each row of moving paddles passes and is scraped by a row of the stationary arms; thus the stationary arms comb the plastic coal from the moving paddles and keep them clean. This method of handling the plastic condition of coal in an agitated coking retort is an ingenious one and operates successfully at Fairmont.

The distillation gases leave the retort through a vapor line and are cooled and cleaned in the usual way.

The semi-coke from the primary retorts is collected and briquetted, using pitch from the tar as a binder. The briquettes are delivered to the second, or carbonizing stage which is conducted in a bench of horizontal ovens placed one above the other in a brick furnace with hollow arches between ovens. The briquettes are charged into the ovens on metal trays and are carbonized by radiant heat from the top of the ovens. The operation is conducted at a temperature of 1200 deg. F. and is completed in 30 minutes. After carbonizing the briquettes are quenched in water and stored for sale.

(For a more detailed description the reader may refer to the Proceedings of the International Conference on Bituminous Coal published by Carnegie Institute of Technology, Pittsburgh, Pa.)

The yields from one ton coal are given as follows:

**Primary Retort:**

|                            |                                |
|----------------------------|--------------------------------|
| Low Temperature Coke.....  | 1480 lbs. (8-12 per cent vol.) |
| Low Temperature Tar .....  | 31 gal.                        |
| Light Oil (from gas) ..... | 2 gal.                         |
| Gas .....                  | 3000 cu. ft. (950 B. t. u.)    |

**Secondary Retort:**

|           |                             |
|-----------|-----------------------------|
| Gas ..... | 2000 cu. ft. (450 B. t. u.) |
| Tar ..... | 8 gal.                      |

### The Greene-Laucks Process

The Greene-Laucks process as operated at Waukegan, Ill., by the Old Ben Coal Corporation, cokes coal in a vertical, cast iron cylinder 18 ft. high and 3 in. diameter at the bottom (40 in. diameter at the top to allow taper). Within this vertical cylinder revolves a centrally located iron pipe rotor about 20 in. diameter having attached to its outer surface a three thread, helical flight extending from the rotor to the retort walls and having a pitch varying from 12 in. at the bottom to 16 in. at the top. The retort is set in a furnace arranged for external heating of the outer shell and for the internal heating of the rotor. The coal is fed into the helical flights at the bottom of the retort and is moved upwards by the flights between the heating surfaces bounded by the rotor and the outer cylinder. The coked coal is discharged at the top. The gases of distillation travel upward through the space between the top of the coal and the bottom of the next upper flight and leave at the top through a vapor pipe. The coking temperature is about 800 deg. F. while the capacity of the retort varies with conditions, but is said to average one ton per hour. (For a more detailed description see Proceedings of International Conference on Bituminous Coal.)

The yields from one ton coal are given as follows:

|                           |                              |
|---------------------------|------------------------------|
| Low Temperature Coke..... | 1500 bls. (18 per cent vol.) |
| Low Temperature Tar ..... | 20 gal.                      |
| Gas (surplus) .....       | 1000 cu. ft. (860 B. t. u.)  |

### The K. S. G. Process

As operated at the Mathias Stinnes Mines, Essen, Germany, this process conducts low temperature carbonization of coal in a double inclined rotary kiln described generally as follows:

Two concentric cast iron cylinders, arranged one within the other, are rotated together about a slightly inclined axis. The two cylinders are mounted in a furnace arranged to apply heat to the outside of the outer cylinder. The raw coal is fed into the lower

end of the inner cylinder, is carried upwards in the inner cylinder by means of flights attached to the inside of the inner cylinder, is then discharged from the upper end of the inside cylinder into the annular space between the cylinders and out at the lower end of the outside cylinder into a coke discharge and sealing chamber of special construction. The function of the inner cylinder, which is operated not above 300 deg. C., is that of dehydrating, or preheating, the raw coal by radiant heat from the outer cylinder, before being subjected to the coking temperature of 450-500 deg. C. in the outer cylinder. Superheated steam is sometimes passed into the inner cylinder to prevent plastic coal from agglomerating into large lumps and to assist in initial coking.

The plant has been in operation for about a year. The yields per ton coal are reported to be as follows:

|                            |              |
|----------------------------|--------------|
| Low Temperature Coke ..... | 1640 lbs.    |
| Low Temperature Tar .....  | 20 gal.      |
| Gas .....                  | 2500 cu. ft. |
| Light Oil .....            | 1 gal.       |

Of interest is the fact that this process makes use of the "dry quenching" of the coke by means of inert gases and that the combustion flame around the outer cylinder is softened in temperature by recirculation of flue gases. (For a more detailed description see Combustion for October, 1925.)

### The Thyssen Process

The Thyssen process which has operated for some time in Germany and which will shortly have trial in this country operates as follows:

The coal is coked in a single horizontal cylinder having a continuous spiral on the inside to cause the coal to move forward and discharge at the opposite end. The entire retort is enclosed in a setting and is fired externally. In the interior of the rotating tube, and rotating with it, is another smaller tube, centrally located, placed for the purpose of leading off the products of distillation. The retort is not claimed to be applicable to coals which become very plastic during coking and in this respect the process is limited.

The yields from one ton coal are given as follows:

|                           |                             |
|---------------------------|-----------------------------|
| Low Temperature Coke..... | 1400 lbs. (7 per cent vol.) |
| Low Temperature Tar ..... | 25-40 gal.                  |
| Gas (1000 B. t. u.) ..... | 3-4000 cu. ft.              |

### The Carbocite Process

This is the two-step process originating with Mr. Clarence Wisner and operated at Canton, O. The first step in the process is that of pre-heating or "Thermozing" the coal by means of the sensible heat in a current of hot air and the subsequent coking of the "Thermozed" coal.

The first step is carried out in a rotary kiln heated internally by a current of hot air and externally by the waste of gases from the furnace of the second step. The first kiln delivers its preheated coal to the second and similar kiln except that the second kiln is heated externally only by combustion gases generated in a furnace surrounding the kiln. The waste gases from the furnace pass around the second kiln to supply its external heat. The coking temperature is about 1200 deg. F.

One "Thermozing" kiln 8 ft. in diameter by 125 ft. long feeds two coking kilns of like size. The heat supply is derived from the combustion of part of the gas derived from the process. The capacity of the unit is 400-500 tons coal per day.

The yields from one ton coal are given as follows:

|                                    |                              |
|------------------------------------|------------------------------|
| Low Temperature Coke.....          | 1600 lbs. (11 per cent vol.) |
| Low Temperature Tar .....          | 30 gal.                      |
| Gas (surplus) (880 B. t. u.) ..... | 2600 cu. ft.                 |
| Light Oil .....                    | 1 gal.                       |

### The L & N Process

As operated in England, this process consists in coking coal by means of the sensible heat in combustion gases passed counter-current-wise to a flow of raw coal in an insulated inclined rotary kiln. The maximum coking temperature is about 1200 deg. F. From 25 per cent to 30 per cent of the coal to be coked is pulverized and fired with slight excess of air in a combustion chamber; the remaining 70 per cent to 75 per cent of the coal is fed to the retort to be coked. The hot coke leaving the retort partly reacts with the CO<sub>2</sub> in the combustion gases, generating CO and thereby reducing the temperature of the gases. Thus the actual gas which conducts the coking is really a form of producer gas.

The retort is about 90 ft. long by 7 ft. diameter and turns at about one-half revolution per minute. The coal capacity is about 100 tons per day. The yields per ton are given as follows:

|                           |                            |
|---------------------------|----------------------------|
| Low Temperature Coke..... | 900 lbs. (5 per cent vol.) |
| Low Temperature Tar ..... | 20 gal.                    |
| Gas (250 B. t. u.) .....  | 44,000 cu. ft.             |
| Ammonium Sulfate .....    | 15 lbs.                    |

### The Bussey Process

This process, as operated at Louisville, Ky., consists literally of maintaining combustion in the lower portion of a vertical column of coal confined within a brick-lined shaft and in removing the products of combustion together with the products of distillation from the shaft by drawing or forcing them through the coal. The carbon residue, or coke, is removed from the base of the shaft as formed by means of a suitable mechanism and fresh coal is added at the top of the shaft through a seal as the charge settles by gravity.

The retorts are brick-lined steel shafts having the form of a truncated pyramid and measure 4 ft. square at the top by 8 ft. 3 in. at the bottom by 30 ft. high. The retort handles from 12 to 23 tons coal per day, depending upon the type of coal.

Yields from one ton coal are given as follows:

|                           |                             |
|---------------------------|-----------------------------|
| Low Temperature Coke..... | 1500 lbs. (4 per cent vol.) |
| Low Temperature Tar ..... | 25 gal.                     |
| Gas (250 B. t. u.) .....  | 20,000 cu. ft.              |

### The McEwen-Runge Process

This ingenious method conducts the coking of pulverized coal by dusting the coal downwards in a tower against an ascending current of hot circulating gases. The plant now in operation at Milwaukee, Wis., consists of two vertical steel plate retorts, or towers, 40 ft. high by 6 ft. 9 in. diameter, one superimposed upon the other. The retorts are cylindrical in shape except that at a point 11 ft. from the top each retort flares up and out to a top diameter of 13 ft. The retorts are lined with fire brick backed up by insulation.

The method of heating is common to both retorts—each retort is equipped with two tangential combustion chambers at the bottom of the shell. High pressure gas burners deliver hot combustion gases into the bottom of each retort. The pulverized coal

is fed in at the top through a feeder, is coked as it falls through the ascending hot gases and the coke is collected at the bottom where it is quenched with steam. The coke is then pulverized for boiler firing. The unit has been operated at the rate of nine tons per hour.

The yields from one ton coal are given as follows:

|                                     |              |
|-------------------------------------|--------------|
| Low Temperature Coke .....          | 1400 lbs.    |
| Low Temperature Tar .....           | 25-30 gal.   |
| Gas (850 B. t. u. equivalent) ..... | 3700 cu. ft. |

### The Economics of Low Temperature Carbonization

The theoretical ability of low temperature carbonization to produce a higher yield of aggregate values in the products of coal distillation is the rational reason usually assigned to the existence of the method. There is less degradation of the primary oils and gases from the coal into carbon (and low value hydrocarbons) and therefore less loss in available values. Such a system should make for efficiency and conservation. It is not enough, however, that the thermal efficiency of the process be higher, and that the total thermal value of tar, gas and coke be greater than the tar, gas and coke from the high temperature process, but there must be a commercial value for these products to justify their production. To make the low temperature carbonization system an economic success, there is needed, therefore, a steady and permanent market for the products at a price that will yield profits. Unfortunately, low temperature carbonization has not yet been conducted successfully on a scale sufficiently large to establish the value of its products. The gas and coke can be said to have a definite commercial value above that of high temperature products, but low temperature tars have yet to have a proper value placed upon them.

If one may speculate, it would appear that the fields for low temperature carbonization lie (1) in supplementing the established systems for making gas by supplying a gas of high calorific value to replace carburetion of water gas with gas oil (which is constantly mounting in price due to its use by its producers for cracking into motor fuel), (2) in supplementing the present supplies of anti-knock blends from low temperature tar oils (experiments on a commercial scale have shown that excellent motor fuel yield can be had from low temperature tars), (3) in supplementing low volatile coals from mixtures in high temperature coking to improve coke quality, (4) in the production of a smokeless fuel (America's annual "smoke bill" is an enormous figure and low temperature coke makes an excellent domestic fuel of smokeless and free-burning variety, but unfortunately, in many districts soft coal itself would be the competitor of coke made from it because of its price), (5) for pre-carbonization of coal at points of large consumption, particularly Central Power Stations. This field appears to offer the most likely field for present development because of the economics that can be effected in the generation of steam through the sale of tar and rich gas.

It is interesting to note the results of large scale experiments that have been conducted by the Universal Oil Products Company in cracking low temperature tars by the Dubbs process. The yield of motor fuel is over 20 per cent and when we are reminded that the chemical makeup of low temperature tar oils is such as to place them in the front rank



of anti-knock motor fuel blends it would appear that this field would be a profitable venture.

Again, low temperature tars as a class are notably high in tar acids which constitute the basis of our synthetic resin (bakelite) industry. One gallon of low temperature tar will sometimes yield five times as much acids as the best high temperature tars.

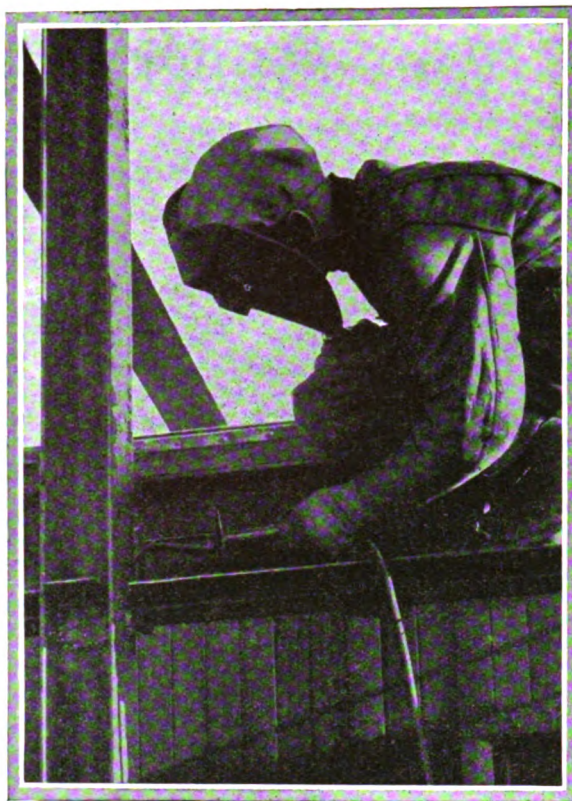
It has been the intent of this paper to give a general picture of what has been accomplished in low temperature carbonization in actual commercial trial. Numberless processes on experimental trial in a small way and proposed new processes command the intense interest of those who are keen on the subject and their description has not been attempted. The fact that millions of dollars representative of money, labor and technical effort have been spent in the development of low temperature carbonization to the point where its commercial advantages are becoming apparent, should lead all of us to foster and hasten the development of an industry which holds much in store in the way of potential possibilities and profits.

### First Arc-Welded Structural Steel Building in West

Arc welding of structural steel has "gone west." The first building west of the Colorado River, to have arc welded joints throughout has been erected at Denver, Colo., for the Colorado Compressed Gas Corporation and is another step in the successful application of arc-welded structural steel to building operations. There is not a single rivet or bolt in this entire building which is of saw-tooth structure with two bays 50 ft. by 50 ft. by 25 ft. high. It represents an outlay of approximately \$50,000 and was completed in 8½ actual working days.

This electrically arc-welded structural building is the first unit of the manufacturing plant of the Colo-

The enclosure of such a building should be of such material as will afford the best heat insulation and at the same time not possess the characteristics of a rigid structure such as would result in the use of masonry for the enclosing walls. To best meet these requirements it was decided to use a special

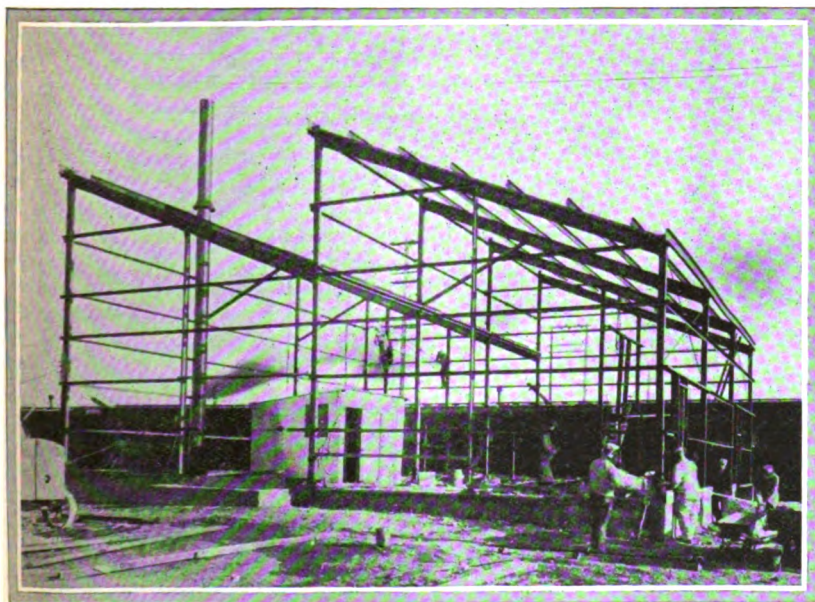


asbestos-protected metal manufactured under the Robertson process. This processed metal has withstood the tests of the government and is being utilized quite extensively by the government in the building of balloon hangars. It is made by combining steel sheets, asbestos and asphaltic compounds, which are covered with a surface coating of aluminum. The aluminum coating is utilized to deflect the heat rays from the sun and with the asbestos insulation, operates to give a satisfactory insulated building during the heat of summer, which is a fundamental requirement in the manufacture of acetylene gas.

The Midwest Steel & Iron Works of Denver, Colo. erected the structural steel and in doing so electrically arc-welded every joint in the entire structure using a 200 ampere Westinghouse portable arc welder. Twenty tons of steel were used in the erection. The uprights are 5-in. H and the girders 12-in. I beams. Picture at left shows the steel frame of the building in a stage of completion and brings out clearly the absence of riveted joints. Top picture shows an operator performing a weld-

ing job on one of the joints.

Robert K. Fuller of Denver was the architect on this building which was erected by the contracting firm of A. Danielson & Son.



rado Compressed Gas Corporation manufacturers of acetylene gas. In the design of the building it was necessary to consider the requirements of a building wherein such a product is manufactured.



# The POWER PLANT

## *New Power Plant at Steel Works\**

**A Comprehensive Description of the Equipment Installed In One  
of the Most Modern Power Generating Stations. Blast Fur-  
nace Gas and Powdered Coal Burned Under Boilers**

By H. W. NEBLETT†

**I**N recent years executives and engineers in steel plants have come to realize that while power and steam cost represent comparatively only a small percentage in the total cost of producing finished steel, the total annual cost of these items amounts to an enormous sum, and the possibility of large returns from investments in modern power plant and electric mill drive equipment is assured. The average steel plant engaged in the production of pig iron, the manufacture of steel, and the rolling of the various steel products, is favorably situated for utilizing the benefits from the modern steam driven electric generating plant.

Fuel for the boilers is available in the form of blast furnace gas, and in most cases, other fuel, such as coke braize, and slack or screenings from coal. The rolling of steel products in the various mills requires large quantities of electric power and the number of mills is usually great enough and the loads so diversified that a large and fairly constant electric load is available during the 24 hours of the day. Blowers are required for supplying air to the blast furnace. Where these blowers are steam turbine driven they can be installed in the power house with the turbo-generators, thus insuring a more diversified and steady steam demand.

Many steel plants abandoning the various steam engine drives with their isolated boiler plants, low steam pressure, high labor and maintenance cost, and poor efficiency, and are installing electric motor drives for the mills, supplied with power from a centralized power plant.

The Colorado Fuel & Iron Company has followed this trend by recently installing a power plant and electric drives for their mills in the Minnequa Steel Works at Pueblo, Colo. This power plant has made possible great savings in the production of steel by the elimination of many steam engine drives and isolated boiler plants. A total of 75 boilers in five boiler plants have been eliminated to date and when the electrification program, for which the new power plant is designed, has been fully extended, a total of 118 boilers will be abandoned.

Minnequa Steel Works is equipped for the complete process of steel making from iron ore to the finished steel. It manufactured a large range of steel products, from railroad rails to a variety of wire pro-

ducts, which requires a large amount of power for the rolling and finishing operations.

The new power plant is a complete unit consisting of a power house, boiler house, powdered coal plant, and gas cleaning plant. It is operated as a separate department with a complete organization including testing, combustion, and efficiency engineers, and a complete equipment of laboratory, testing and operating instruments. In its relations with the other departments of the steel plant it is operated as a utility, purchasing its fuel in the form of blast furnace gas or coal and selling electric power, steam, blast air, and water. The power plant is located adjacent to the blast furnaces, enabling the gas to be easily delivered to the boiler house.

### Power House

Two main turbo-generator units are installed in the power house and a third unit is in the course of erection. These units are 10,000 kw. (12,500 kva.), 6,600 volt, 3 phase, 60 cycle. The generators are cooled by air circulating in a closed system. The heated air from the generator passes over water cooled pipe coils and is returned to the generators. Thermostatic controlled doors are provided which will open and admit fresh air from the power house in case the temperature of the circulated air becomes excessive due to a failure of the cooling system.

The generators are connected to a main 6,600-volt bus to which is connected the main power feeders to the mills and a tie line to the Southern Colorado Power Company for the exchange of power. This tie line also acts as an emergency supply for auxiliary equipment in case of generator trouble. The main bus also feeds an auxiliary 6,600-volt bus through a 5 per cent reactance which permits oil switches of smaller rupturing capacity to be installed on the auxiliary 6,600-volt bus. The small capacity feeders for miscellaneous power throughout the plant are connected to the auxiliary bus. It also feeds, through a transformer bank of 1,500 kva. capacity, a 2,300-volt station bus, to which is connected the motor driven auxiliaries for the power house, such as exciters, circulating water, and spray pond pumps.

An extension on the east side of the power house provides for the switchboards, offices, and laboratory, which are located at the same elevation as the main operating floor of the power house. The first floor, or basement, below the switchboard is used for a bus structure and cable room; also, one section is par-

\*Colorado Fuel and Iron Company.

†Chief Engineer for Wilfred Sykes, Consulting Engineer, Colorado Fuel and Iron Company.

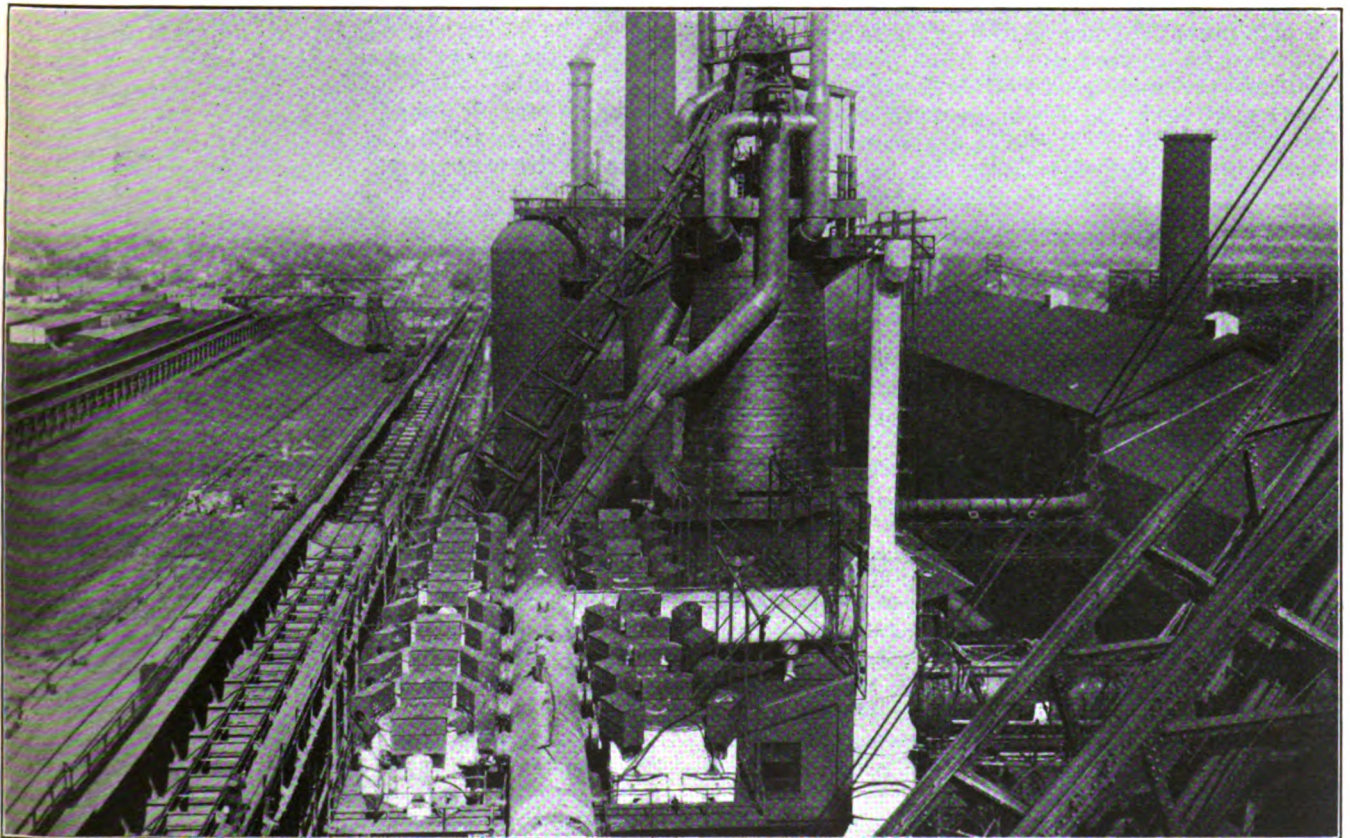


tioned off and houses a ventilating system for delivering washed fresh air to the power house. The bus structure is made up of reinforced concrete and accommodates all high voltage equipment, including oil switches, disconnects, instrument and current transformers.

Four turbo-blowers are installed for supplying air to the blast furnaces, and are so connected to the cold blast lines leading to the stoves of the blast furnaces that any blower can be connected to any one of three furnaces. These blowers are rated at 55,000 cu. ft. of air per minute at 25 lbs. pressure for the altitude at which they are installed, namely, 4,800 ft. This corresponds to a rating of 60,000 cu. ft. at sea level.

An oil purifying system is installed in the power house for maintaining a supply of pure oil to the bearings of the main units. Each turbo-generator and turbo-blower has its individual oil circulating system and reservoir which is an integral part of the unit. The oil from the reservoir is circulated over the bearings of the unit either by pumps driven from the shaft of the unit or by steam. In addition, the reservoirs in each unit are connected to a storage tank of 1,000 gal. capacity in the basement. Used oil can be drawn from any of the reservoirs in the units and discharged by gravity into this storage tank. From this storage tank the oil is passed through a centrifugal oil purifier which removes all dirt and moisture and the cleaned oil is then pumped into a clean oil storage tank of 1,000 gal. capacity located near the ceiling of the power house. A pipe line from this clean oil storage tank connects to the reservoir in each unit. In this way a constant supply of cleaned oil is maintained for the main units at all times. The main units operate on steam at 330 lb. pressure and 200 deg. F. superheat and are equipped with surface condensers.

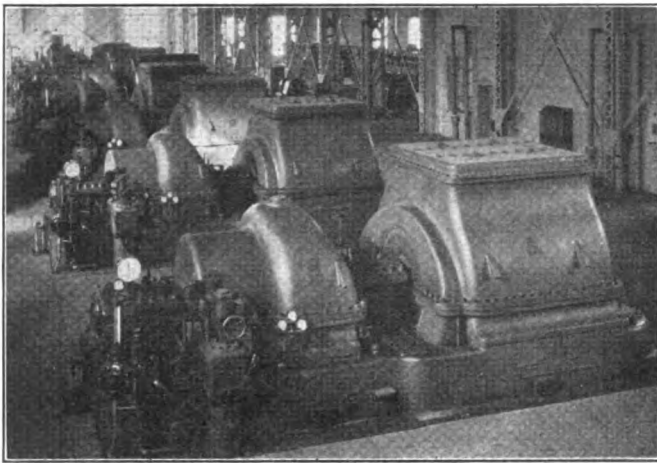
The auxiliary equipment in the power house consists of two 150-kw., 250-volt motor drive, and one 150-kw. steam driven exciter for supplying excitation to the main generators; two 1,000-kw., 250-volt d.c. motor generator sets feeding the d.c. power system of the steel plant adjacent to the power house; two 200 kw. dual drive, 250-volt d.c. generators for supplying power to the various d.c. motors of the power house, boiler house, powdered coal plant, and gas cleaning plant. These dual drives perform two important functions: First, they insure uninterrupted power for station use; second, they furnish exhaust steam as required, in addition to exhaust steam from other sources, for the boiler feed water treating and heating equipment. These dual drive sets consist of a d.c. generator directly connected to, and driven by, a 2,300-volt a.c. motor and a non-condensing steam turbine. The turbine is equipped with a regulating governor which will automatically take the entire load on the turbine in case the power supply to the motor fails. Also, by means of a regulating valve any portion of the load may be taken on the turbine. In this way a varying amount of exhaust steam may be furnished for boiler feed water treating as required. The boiler feed water for the boilers supplying high pressure steam for the power house consists of the condensate from the turbo-blowers and turbo-generators, plus the necessary make-up, or raw water required. Each condenser is equipped with duplicate hot well pumps driven by 230-volt d.c. motors which are connected to separate feeders fed from the dual drive sets. The hot well pumps deliver the condensate to a reserve feed water storage tank which acts as a reservoir to take up the fluctuations in the load. From this reserve feed water tank it is delivered to a deaerator which is connected with the evaporators for treating



View overlooking Electric Precipitators and Blast Furnace.



the raw make-up water. The evaporators remove all scale forming matter from the raw water and deliver it to the deaerator where the entire boiler feed water is deaerated to the extent that the oxygen content is below .05 cc. per litre. From the evaporator and deaerator equipment pure boiler feed water is delivered to the boiler feed pumps at approximately 105 deg. F. The evaporator and deaerator equipment has a capacity of 350,000 lb. of boiler feed water per hour. There is also installed a soda-lime hot water softening plant of 125,000 lb. per hour capacity for supplying feed water to the low pressure boilers which supply steam at 150 lb. pressure for general use in the steel plant. The steam for the two boiler feed water treating plants is supplied by the exhaust from the boiler



Blast Furnace turbo-b'lowers.

feed pump turbines, the steam driven exciter, and the turbines on the dual drive sets. This exhaust steam has a maximum pressure of 10 lb. There are four turbine driven boiler feed pumps, each with a capacity of 600 gal. per minute at 860 ft. head. Two motor driven centrifugal water pumps with a capacity of 12,000 gal each at 55 ft. head are installed for circulating condensing water from the condensers to a spray pond. Three motor driven centrifugal water pumps with a capacity of 6,000 gal. per minute, each at 130 ft. head, are used for pumping blast furnace drain water into the main water system for steel plant use. A motor driven Nash vacuum pump is installed for priming the water pumps. All pumps are located in the basement. The exciters, motor generators, and dual drive sets are located on the main floor of the power house.

### Water Supply

The water for condensing purposes is provided in an unusual manner. The steel plant is located in a section of the State of Colorado where the average annual rain fall is 12 in. or less. Practically all water available in this locality is from the snow banks in the Rocky Mountains, the nearest range of which is about 35 miles west of Pueblo. Very strict legislation pertaining to water rights exists in this section on account of the limited supply. The water supply system of the Colorado Fuel & Iron Company is necessarily extensive and complicated. In order to insure a constant supply, the company maintains large storage reservoirs in the mountains and near the steel plant with necessary canals and pipe lines. The total water supply for the steel plant, which is approxi-

mately 32,000,000 gal per day, is delivered by gravity at 50 lb. pressure through pipe lines from storage reservoirs located approximately 5 miles from the steel plant. The water supply system is so arranged that all of the water for the main steel plant is used for condensing purposes by first passing it through the condensers of the turbo-blowers and turbo-generator in the power house, which discharge into the water mains of the steel plant. Water that is used around the blast furnace is collected in a sump in the power house, from which it is pumped back into the system ahead of the condensers, thus utilizing this additional water for condensing purposes. In case of failure or shortage of water from the main water supply, an emergency supply can be taken from an irrigation canal which runs through the plant. Water from this canal is taken through settling basins and is pumped into the water mains ahead of the condensers. To insure sufficient cooling water at all times for the condensers, a spray pond with a capacity of 27,000 gal. per minute is provided. Water for the initial spray pond supply and for make-up to replenish evaporation can be either taken from the main water system or from an auxiliary storage reservoir located about one mile from the plant. The condensers in the power house are so arranged that any one, or all, can be connected to either the main water system or the spray pond which is located at an elevation that permits the cooled water to flow through the condensers by gravity. The discharge from the condensers, when operating on the spray pond, is taken by two 12,000 gal. per minute motor driven pumps and delivered to the nozzles of the spray pond. On account of the relative low humidity at Pueblo this spray pond gives very effective cooling.

### Boiler House

The boiler house is located adjacent to, and in line with, the power house. Seven 1,200 hp. Stirling type water tube boilers, without economizers, are installed which are designed for operation at 330 lb. steam pressure and 200 deg. F. superheat. Until such time as all the present steam consuming units are replaced with electric drive, one, and sometimes two of these boilers, will be operated at 150 lb. steam pressure. This low pressure steam is delivered from the boiler house into steam lines connecting to the various low pressure steam consuming units in the steel plant, such as mill engines, hydraulic pumps, etc. When the demand for this low pressure steam has been eliminated, all boilers will be operated at 330 lb. steam pressure. This change can be made without any change in equipment as all boilers, valves, steam lines, and auxiliaries are designed for operation at the higher pressure.

The boiler settings are brick of solid wall construction, no air cooling being provided. The inside walls of the settings are arch construction, so designed that the expansion of the bricks cause the wall to tend to move outward. The outward movement, due to the expansion, is taken care of by a steel framework of buckstays which are held together with heavy springs under compression. These springs allow sufficient movement of the steel binding to conform with the expanding of the boiler setting. This boiler setting is sufficiently flexible to prevent cracks through the walls; also the arched construction of the inside or combustion face of the walls tends to hold the brick together under expansion, thus pre-

venting cracks. The combustion chamber is liberal to permit a high rating to be carried on the boilers.

Blast furnace gas and powdered coal are used for fuel. Two boilers are equipped for burning blast furnace gas only, and five boilers are equipped for burning both blast furnace gas and powdered coal. Each boiler is equipped with four horizontal gas burners of the aspirating type in which the air for combustion is mixed with the gas. These burners have a capacity of 2,000,000 cu. ft. of gas per hour for each boiler. The gas supply is delivered to the boiler room through a gas main 8 ft. 8 in. diameter which connects through a water seal to a gas box in front of each boiler. On each box are located four valves for controlling the gas to the burners. Blast furnace gas constitutes the main fuel. Due to a new method of cleaning, this gas is delivered to the boilers at an average temperature of 375 deg. F., and in addition to the sensible heat retained, it is in an ideal condition for burning. Powdered coal is used only when there is a shortage of gas for short periods during blast furnace cast.

Powdered coal is delivered to each boiler through eight burners located near the top of the combustion chamber and 17 ft. above the gas burners. The coal is fired vertically, thus allowing a long flame travel and complete combustion before reaching the boiler tubes. Powdered coal is fed to the burners by screw feeders driven by adjustable speed d.c. motors, the control of which is located on the operating floor allowing easy regulation of the quantity of coal fired. Approximately 30 per cent of the air required for combustion is delivered under pressure through the burners with the coal. The additional air required is admitted to the combustion chamber through three rows of air doors located in the front wall of the boiler setting. Each row of doors is independently operated to allow for proper adjustment of air. A powdered coal bin of 30 tons capacity is provided at each boiler. The coal is delivered by gravity from the bins to the screw feeders. A maximum of six tons of coal per hour can be fired at each boiler. This will give a boiler rating of over 300 per cent.

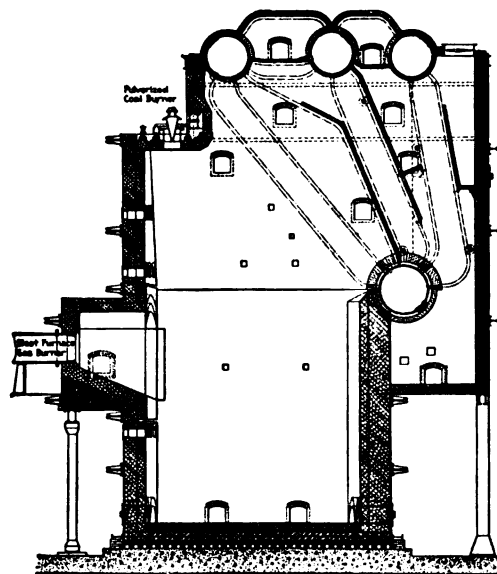
A very small amount of ash is deposited in the boiler settings, the majority passing out the stack with the flue gases. No hoppers or chutes are provided in the boiler settings. The ashes are removed approximately once a week through cleanout doors located in the bottom of the combustion chamber, loaded into a small car which discharges into a skip hoist, and delivered to a storage bin outside the boiler house. No water screens are required as the combustion chambers are so designed that the bottom is sufficiently cool to prevent slagging.

Short individual stacks are installed for each boiler. The draft is maintained by an induced draft fan at each boiler driven by an adjustable speed d.c. motor. The speed of the fan is controlled by a regulator which maintains approximately  $-\frac{1}{2}$  in. draft in the combustion chamber at all times, irrespective of the quantity of gas or coal fired. This maintains a uniform combustion condition for all loads on the boiler. The exit temperature of the flue gases from the boilers average 600 deg. F.

Feed water at approximately 200 deg. F. is delivered to the boilers from the boiler feed pumps in the power house. Water level is maintained in the boilers by duplicate feed water regulators. Blowing down of the high pressure boilers is not necessary as pure water is delivered by the evaporating and deaere-

ating equipment. These boilers are kept in service continuously except for periodic inspection. Superheaters are installed between boiler tubes which give uniform superheat under varying load. Steam at 330 lb. pressure and 200 deg. F. superheat is delivered to duplicate 12-in. steam headers which connect to the main units in the power house. All steam piping is made up with male and female joints. All fittings and connections are welded as a precaution against leakage of steam.

The boiler used for low pressure steam at 150 lb. can also be connected to the high pressure steam headers. In this way any or all boilers can be operated on the high pressure steam system.



Cross section of 1200 hp. boilers showing location of powdered coal and gas burners.

The present average load on the high pressure boilers is 300,000 lb. of steam per hour with peaks of 340,000 lb. per hour, or an average of 60,000 lb. per hour per boiler. The low pressure steam load averages 50,000 lb. per hour per boiler.

#### Powdered Coal Plant

A central coal pulverizing plant with a capacity of 18 tons per hour is installed in a separate building located approximately 100 ft. from the boiler house. A central system was decided on rather than a unit system for each boiler on account of less total pulverizing capacity required; the elimination of raw coal conveying and storage equipment in the boiler house, and greater flexibility. Since powdered coal is used mainly as an auxiliary fuel, comparatively little coal is required over a period of a day or week, but the demand may be heavy for short periods of from a few minutes to a half hour due to a shortage in gas supply when furnaces are casting or are down or changing tuyeres, etc. With a central coal pulverizing system and powdered coal storage bins at the boilers, these heavy demands can be taken care of with comparatively small coal pulverizing equipment, which, under ordinary conditions, need not be operated but a few hours of each day. The advantage of the unit system in not requiring the coal to first be dried is not a factor in this case because the coal in this territory contains very little moisture and the majority of the time can be pulverized and stored

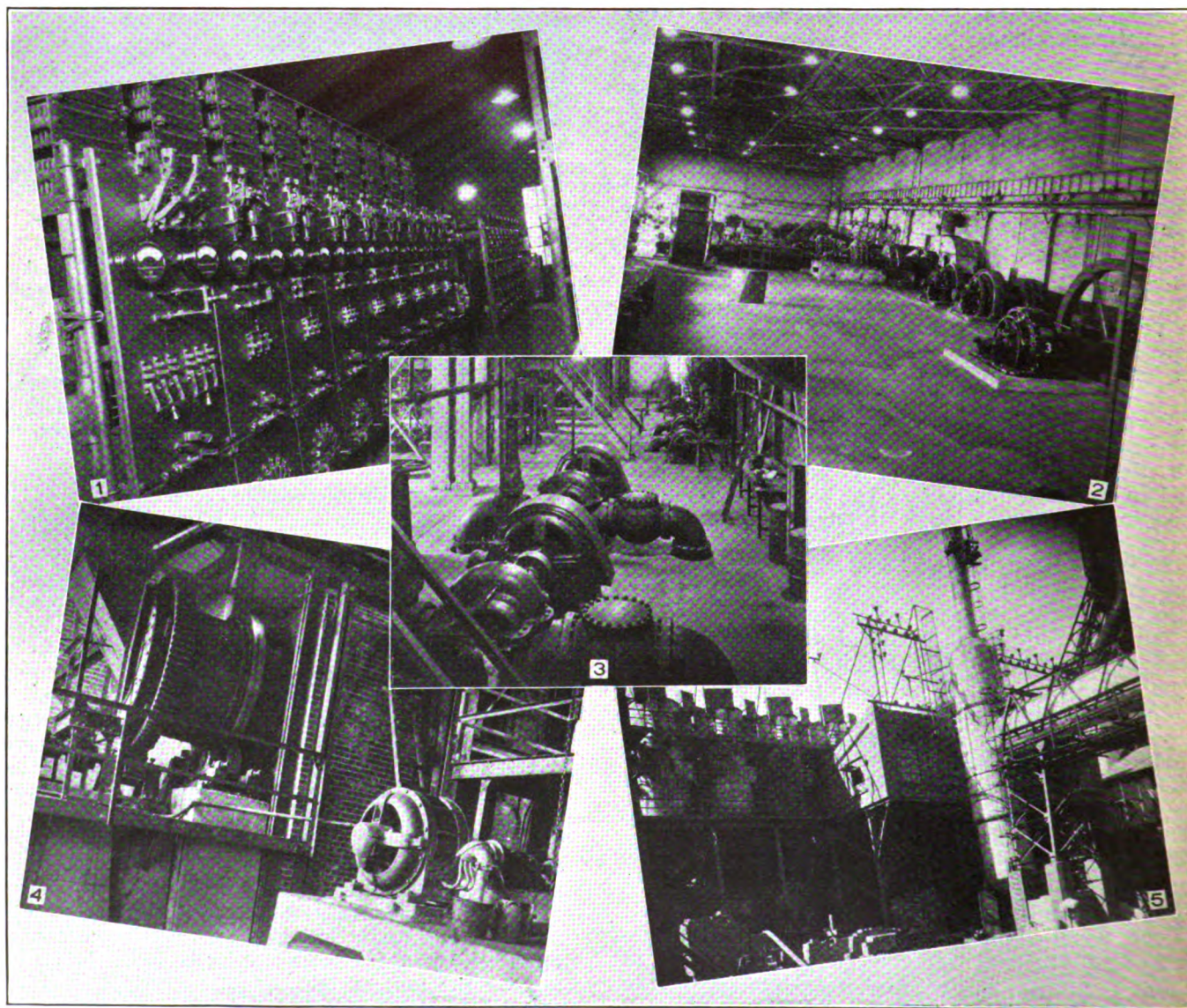


without drying. However, a dryer is included in this installation for use at times when the surface moisture of the coal is high on account of transporting through rain or snow. Pulverized coal can be stored in the bins above the boilers for several days as the temperature around the bins is sufficient to prevent caking of the coal.

The coal pulverizing equipment consists of three rotating ball screen type pulverizing mills with a capacity of 6 tons per hour each; one indirect fired rotary coal dryer; two 6-in. Fuller-Kinyon pumps; one 50-ton raw coal bin; one 40-ton dried coal bin; one automatic skip hoist with a capacity of 50 tons per hour, handling raw coal from track hopper to receiving hopper; and the necessary auxiliary transporting and conveying equipment including conveyors, chutes, and spouts, magnets for removing iron from coal, dust collectors, vent piping, and air compressors.

Slack coal from the company's mines, or screenings from the coal delivered to the coke plant is received in dump bottom railroad cars, weighed and unloaded into a track hopper alongside the powdered coal plant. The coal is taken by a skip hoist to the top of the building and dumped into a hopper from which

it passes over a magnet for removing any tramp iron that it may contain. It is then conveyed either to the raw coal bin or to the dryer. After passing through the dryer it is delivered to the dry coal bin. From either the dry or raw coal bins the coal is fed by gravity into the pulverizing mills. The pulverized coal is delivered from the mills to the Fuller-Kinyon pumps which pump it, after it has been sufficiently aerated to flow freely, through a 5-in. transport pipe to the storage bins located above the boilers. A remote control and signal system is installed in connection with the transport and storage system which allows the operator to control the flow of coal into any storage bin and also indicates which bins are full or need replenishing. All equipment is driven by electric motors, the control of which are assembled, with the transport signal system, in such manner that the operator can control any part of the operation from one central point. The entire coal pulverizing, conveying and storage equipment is dust tight. The storage bins are vented outside the building. No coal dust or dirt is allowed to accumulate around the pulverizing equipment or boilers. No open electric switches are installed in the powdered coal plant,



(1)—Control Switchboards for precipitators. (2)—Motor room of rod mill. (3)—Power house basement. Water pumps in foreground. (4)—Raw coal dryer. (5)—General view of precipitators.



and all electric lights are protected with gas tight shields. The buildings present a clean appearance at all times and the hazard of explosion is practically eliminated.

### Gas Cleaning Plant

Blast furnaces produce a large quantity of gas as a by-product which is available as fuel. Each blast furnace of the Colorado Fuel & Iron Company produces an average of 55,000 cu. ft. of gas per minute measured under standard conditions of 60 deg. F. and 30 in. barometer. This gas contains approximately 98 Btu. per cu. ft. It leaves the blast furnace at about 400 deg. F. temperature and contains an average of 4 grains of dust per cu. ft. of gas, and at times this will be as much as 6 grains. This dust is composed of 42 per cent iron, 11 per cent carbon from coke, and the remainder is dust from limestone and ordinary dirt from the ore. This dust, on account of the high iron content, is valuable after being recovered and prepared in a sintering plant for recharging into the blast furnaces. If the dust is left in the gas it will seriously interfere with the efficiency of the gas as a fuel, as it will be deposited as slag on the boiler tubes and settings; also on the brick checkers in the blast furnace stoves. Approximately 30 per cent of the total gas from the blast furnace is used, after cleaning, for heating the stoves. The remainder is used at the boilers for making steam.

The usual method of cleaning blast furnace gas is the wet washing method employing water. This method, while effective in cleaning the gas, has several disadvantages, namely, the sensible heat in the gas is lost as the gas is saturated with moisture and reduced to approximately 80 deg. F. The gas also carries water in the form of mist which entrains some of the dust. This dust is deposited in the gas mains or is liberated at the burners. In order to eliminate these disadvantages, it is necessary to heat the gas after wet washing which involves additional equipment. The washing of the gas requires large quantities of water with the attendant pumping charges. The water as discharged from the gas washer contains the dust in the form of sludge. In order to recover this sludge it is necessary to pass the water through a settling basin or Dorr thickener. The above disadvantages are common to all wet washing installations.

At this plant there exists additional restrictions in that sufficient water for wet washing is not available; also, that the waste water from such a plant could not be returned to the river on account of the river water being used for irrigation purposes. The conditions made it necessary to use some other system for cleaning blast furnace gas.

A cleaning system has been installed which is known as the Cottrell Electric Precipitation Process. This consists of passing the gas through tubes or between partitions, in the center of which are suspended small wires which are insulated from the tubes or partitions. A high voltage uni-directional current is applied to the wires and the particles of dust in the gas pick up a charge when passing through this zone and are deposited on the walls of the tubes or partitions. At regular intervals of approximately once an hour, the current and gas is cut off from each unit and the tubes or partitions rapped, which causes the dust to drop into the lower part of the cleaner. The dust is then discharged into a bin from which it

is dumped into railroad cars and taken to the sintering plant.

The original installation at Pueblo consists of 16 units. Each unit has a capacity of 10,000 cu. ft. of gas per minute, or a total capacity for the installation of 160,000 cu. ft. of gas per minute at the temperature delivered to the units, which averages 380 deg. F. The present units clean the gas from two blast furnaces. Additional units are now being installed which will give a total capacity for this plant of 360,000 cu. ft. of gas per minute.

The original precipitator units are known as the tube type. Each unit is made up of ninety 6 in. diameter pipes. The units now under construction are the plate type and consist of a series of plates or partitions between which the electrode wires are installed. The latter type are much cheaper in first cost and simpler in construction.

The electrical equipment for the precipitators is located in a house adjacent to the unit. This house contains rectifiers, transformers, switching equipment, and control switchboard. There is also installed an automatic electric timing and rapping control. This control automatically cuts off the gas and electrical supply to each unit, raps the dust from the tubes, closes the electric circuit, and opens the gas supply valve. This is entirely automatic and requires no attention from the operator. The units are rapped one at a time in sequence. The interval of time between rapping periods can be varied over a range of 20 minutes to one hour. In addition, a push button is provided on each unit panel which enables the operator to rap any unit at will, in addition to the regular rapping period.

The cleaned gas contains an average of .2 grains of dust per cu. ft. and this figure can be reduced to any amount desired by reducing the flow of gas through the precipitators. The gas is cleaned without reducing the temperature which adds approximately 3 per cent to its heating value.

The absence of moisture provides a better gas for combustion and eliminates the necessity of flushing or washing out the gas mains or burners. The dust is received in a dry form, is easily handled, flows by gravity from precipitators to railroad cars, and is in ideal condition for sintering and returning to the furnaces, thus converting a by-product, ordinarily perplexing to handle, into an iron bearing material of real value in the furnace charge.

The total power required for operating the gas cleaning plant is 80 kw. The equipment being automatic in operation requires a minimum of labor and supervision. The maintenance is negligible, the operating cost is low, and the annual return on the investment is approximately 30 per cent, based on the increased efficiency of the cleaned gas and the value of the dust recovered. This is after all operating and maintenance costs have been deducted.

This gas cleaning plant has been in operation one year and has proved entirely satisfactory. It is the only commercial installation of electric precipitators in America for cleaning the total gas delivered by blast furnaces.

The design and installation of this gas cleaning plant was made after much experimenting and testing with a trial unit extending over a period of approximately three years. The success of the installation is verified by the fact that after one year of operation



additional units are now being installed which will more than double the capacity of the original installation.

### Distribution and Consumption of Power

The current is distributed from the power house at 6,600 volt, 3 phase, 60 cycle a.c., and as 250 volt d.c., on an overhead distribution system supported on structural steel towers. Lightning arresters are installed at both the power house and distributing or mill end of the circuits. The 6,600 volt a.c. current is distributed on individual lines to each mill or department. The 250 volt d.c. current is distributed into a general d.c. distribution system for the plant. The motor generator sets in the power house supply d.c. current to that part of the system in the vicinity of the power house. They also connect by means of tie lines to other centers of d.c. distribution, such as the rod mill, in which two 1,000-kw., 250-volt d.c. motor generator sets are installed. The motor rooms of the different mills act as substations in which the 6,600 volt lines from the power house terminate in a bus structure to which is connected the motors, motor generator sets, rotary converters, and transformers. Here are also located the a.c. and d.c. switchboards for controlling the motors and for the distribution of power.

The electrification of the plant to date includes electric main drives for the following mills: Rail mill; 14-in. merchant mill; 25-in. structural and merchant mill, (new); rod and 10-in. mills. Electric service is supplied to the other departments of the steel plant for general power and light. A transmission line extends approximately 6 miles from the plant to supply service to a company limestone quarry.

A typical motor room is shown in Fig. 2. This shows the motor room of the rod mill. The total of the main drive motors installed in this mill exceeds 11,000 hp. The constant speed drives are 6,600-volt a.c. induction motors directly connected to the mill rolls through reduction gear sets. Where variable speed is required, 600 volt variable speed d.c. motors, supplied from rotary converters, are installed.

The electrification of this steel plant has resulted in a great saving of fuel, maintenance, labor, and operating costs; the saving in coal alone amounting to over 150,000 tons per year, and this will be further increased with the extension of the electrification.

Increased production has resulted from the installation of electric drive on the mills. Every mill electrified has exceeded all previous production records since electric drive has been installed. Mill speeds remain the same as originally. The increased production is due to a more uniform mill speed being maintained than was possible with steam engine drive.

The normal week day electric load on the power house varies from 16,000 to 19,000 kw., depending on the demand from the mills.

The power plant and steel plant electrification was designed, and its construction supervised, by Wilfred Sykes, Consulting Engineer, Chicago.

The electrical equipment, including generators, main drive motors, switchboards, and switching equipment was installed by the General Electric Company.

The machine shops and construction department of the Colorado Fuel & Iron Company, which are modern and well organized handled all construction work, including the fabrication of the structural steel and the making of all castings.

## PRINCIPAL EQUIPMENT FOR THE POWER PLANT AND STEEL MILL ELECTRIFICATION

### General

Location of Plant—Minnequa Steel Works, Pueblo, Colo.  
Elevation—4800 ft. above sea level.

### General dimensions—

Power house—270 ft. by 63 ft.  
Switch house—126 ft. by 30 ft.  
Boiler house—286 ft. by 66 ft.  
Powdered coal plant—66 ft. by 48 ft.  
Gas cleaning plant—170 ft. by 42 ft.  
Spray pond—520 ft. by 125 ft.

### Electrical Equipment

Three turbo generators, 10,000 kw., (12,500 kva.) 80 per cent power factor, 6,600 volt, 3 phase, 60 cycle, 1,800 rpm., 4 pole. Turbine operates on steam at 300 lb. pressure, 200 deg. F. superheat. General Electric Company.

Two motor driven exciters, 150 kw., 250 volt d.c. driven by 2,300-volt, 3-phase induction motor. General Electric Company.

One steam driven exciter, 150 kw., 250 volt d.c. driven by non-condensing steam turbine. Steam pressure 300 lb., 200 deg. F. superheat. Exhausting into header at 10 lb. back pressure. General Electric Company.

Two dual drive generator sets for house service, 200 kw., 250 volt d.c., driven by a 2,300-volt, 3-phase, 60-cycle squirrel cage motor and a non-condensing steam turbine. Steam pressure 300 lb., 200 deg. F. superheat. Exhausting into header at 10 lb. back pressure. General Electric Company.

Five motor generator sets, (two in power house, three in mill motor rooms), 1,000 kw., 250 volt d.c. Supply general d.c. service to steel plant. Driven by 6,600-volt, 3-phase, 60-cycle synchronous motor. General Electric Company.

Four switchboards: One main 6600 volt, controlling generators, main feeders to mills, and a tie line to Southern Colorado Power Company; one auxiliary 6,600 volt controlling small auxiliary power feeders, power for which is supplied from main 6,600-volt bus through a 5 per cent reactance; one 2,300-volt station controlling feeders for station motors. Power is supplied from auxiliary 6,600-volt bus through a 1,500-kw. transformer bank; one 250-volt d.c. controlling motor generator and dual drive sets, the feeders to the d.c. system and for station use. Switchboard is divided in two sections, one for feeders to the d.c. system, the other for power house d.c. service. The two sections can be tied together for emergency supply to power house in case of failure of dual drive sets. General Electric Company.

### Turbo Blowers

Four blast furnace turbo-blowers. Five stage water cooled centrifugal blower. Capacity 55,000 cu. ft. of air per minute at 25 lb. pressure. 2,950 rpm. constant volume governor. Turbine operates on steam at 330 lb. pressure, 200 deg. F. superheat. Ingersoll-Rand.

### Condensers

Three surface condensers for turbo-generators. 15,000 sq. ft. of tube surface, two pass. Each condenser equipped with duplicate steam jet air ejectors and duplicate two stage hot well pumps driven by 10-hp., 250-volt d.c. motors. Wheeler Condenser & Engineering Company.

Four surface condensers for turbo-blowers. 4,000 sq. ft. tube surface. Two pass. Each condenser equipped with duplicate steam jet air ejectors and duplicate hot well pumps driven by 7.5-hp., 250-volt d.c. motors. Wheeler Condenser & Engineering Company.

### Feed Water Treaters

Two Evaporators for boiler feed make-up water. Operate either single or double effect. Capacity 10,000 lb. make-up per hour. Griscom-Russell Company.

One deaerator and heater for high pressure boiler feed 350,000 lb. water per hour. Reduces the total oxygen content to .05 cc. per litre. Delivers pure distilled water for boiler feed. Griscom-Russell Company.

One hot process soda ash-lime water softener for boiler feed for low pressure boilers. Capacity 125,000 lb. per hour. Graver Corporation.

### Pumps

Four boiler feed pumps, A. S. Cameron type No. 4 H.M.T. 3 stage, 600 gal. per minute, 860 ft. head, driven by Westinghouse 195-hp., type MD steam turbines operating on steam at 300 lb. pressure and exhausting into header at 10 lb. back pressure.

Two centrifugal water pumps for spray pond. A. S. Cameron Type No. 18 F.V., 12,000 gal. per minute, 55 ft. head, driven by General Electric 250-hp., 2,300-volt, 3-phase, 60-cycle induction motors.

Three centrifugal water pumps for recirculating water. A. S. Cameron Type No. 18 F.V., 6,000 gal. per minute, 130 ft. head, driven by General Electric 250-hp., 2,300-volt 3-phase, 60-cycle induction motors.

Two centrifugal water pumps for delivering water from reserve feed water tank to feed water system. A. S. Cameron Type No. 3 L.V., 200 gal. per minute, 70 ft. head driven by General Electric 10-hp., 250-volt, d.c. motors.

#### Boilers, Superheaters and Accessories

Seven Casey-Hedges 4-drum water tube boilers. 1,200 hp., 330 lb. steam pressure. Three of these boilers arranged to be operated at either 330 lb. or 150 lb. steam pressure; 330 lb. steam used in power house, and 150 lb. steam used for steam driven equipment in mills not yet electrified. All boilers will eventually be operated at 330 lb. steam pressure.

Fourteen feed water regulators. Operating in duplicate on each boiler. Copes.

Seven superheater installations. Superheater elements installed between boiler tubes in first pass deliver 200 deg. F. superheat to high pressure steam, 150 deg. F. to low pressure steam. The Superheater Company.

Eight soot blowers in each boiler installed in pairs, one on either side, or a total of 16 units. Diamond Power Specialty Corporation.

Seven induced draft fans, one on each boiler. 110,000 cu. ft. per minute capacity against a total static head of 1½-in. water, double inlet. Green Fuel Economizer Company. Each fan driven through a flexible coupling by a 60-hp., 200 to 400-rpm. adjustable speed 250-volt d.c. motor. Speed controlled by a regulator to maintain a draft of .2 in. in the combustion chamber irrespective of the amount of gas or powdered coal fired.

Boiler settings, brick, solid wall construction. Designed for outward expansion. Held by flexible compression spring binding. Design prevents cracks through boiler setting walls. Suspended arches by American Arch Company. No water screens required. Ashes removed through clean-out doors in bottom of setting. Ash handling equipment by Beaumont Manufacturing Company.

Four gas burners installed on each boiler. Horizontal aspirating type. Capacity 2,000,000 cu. ft. of gas per hour per boiler. Gas supply controlled by valve on each burner.

Eight powdered coal burners installed on each boiler. Five boilers equipped. Coal fed by screw feeders. Driven by variable speed d.c. motors. Capacity 6 tons powdered coal per hour. Fuller-Lehigh Company.

Three primary air blowers for powdered coal burners. 20,000 cu. ft. per minute capacity at 6-in. static pressure. B. F. Sturtevant Company. Directly connected to General Electric 60-hp., 60-cycle a.c., 1,170-rpm. motor.

#### Steam Piping

All steam and boiler feed piping 400 lb. American Standard Male and female flanged joints. Fittings and connections welded. Pittsburgh Piping & Equipment Company.

#### Insulation

All insulation for steam and boiler feed piping, boilers, breechings, gas piping and precipitators. Johns-Manville.

#### Coal Pulverizing Plant

One 5 ft. 6 in. x 42 ft. rotary coal dryer. Indirect fired, pulverized coal. Capacity 15 tons per hour. Motor driven. Fuller-Lehigh Company.

Three 46-in. rotating ball, screen type pulverizing mills. Capacity 6 tons per hour each. Motor driven. Fuller-Lehigh Company.

Two 6-in. Fuller-Kinyon pumps and 5-in. transport pipe for pumping coal from powdered coal plant to storage bins at boilers. Capacity 18 tons per hour. Motor driven. Fuller-Lehigh Company.

One automatic skip hoist for delivering raw coal from track hopper to receiving hopper. Capacity 50 tons per hour. Automatic load and dump. Motor driven. Beaumont Manufacturing Company.

One plate type magnet and one magnetic pulley for removing iron from coal before entering pulverizing mills. 250 volt, d.c. Cutler-Hammer Manufacturing Company.

Two air compressors for delivering air to transport line. 250 cu. ft. per minute capacity at 80 lb. pressure. Motor driven. Ingersoll-Rand Company.

Spiral conveyors, drag conveyors, belt conveyors. Jeffrey Manufacturing Company. E. C. Horne Machinery Company. Speed reducers for drives. W. A. Jones Foundry & Machine Company.

Motors for driving equipment. 220 volt, 3 phase, 60 cycle, induction. General Electric Company.

#### Gas Cleaning Plant

Sixteen precipitator units now installed. Capacity 10,000 cu. ft. of gas per minute, each.

Eight precipitator units under construction. Capacity 25,000 cu. ft. gas per minute, each.

Seventeen rectifiers and control switchboards. Research Corporation.

Automatic rapping control equipment. Cutler-Hammer Manufacturing Company.

Seventeen transformers, single phase, 25 kva., 220 volt primary, 65,000 volt secondary. Westinghouse Electric & Mfg. Company.

Air cylinders for rapping and valve operation. Westinghouse Electric & Mfg. Company.

Disconnect switches, bus supports, and special designed air cylinder operated high tension circuit switches. Delta-Star Electric Company.

#### Miscellaneous

One two-section spray pond. Capacity 27,000 gal. per minute. Equipped with 136 groups of spray nozzles. Five nozzles to each group. Capacity of each nozzle 40 gal. per minute at 7 lb. pressure. Spray Engineering Company.

Main drive motors for mills: 6,600 volt, 3 phase, 60 cycle, induction and 600 volt d.c. variable speed; four 3,000 hp., a.c.; two 2,000 hp., a.c.; one 1,200 hp., a.c.; two 1,000 hp., a.c.; three 1,500 hp., d.c.; one 750 hp., d.c.; one 300 hp., d.c.; installed in rail, rod, 10-in. merchant, 14-in. merchant and 25-in. structural and merchant mills. General Electric Company.

Reduction gear sets installed between a.c. motor drives and mills. Falk Corporation.

Oil circulating and purifying equipment for reduction gear sets and bearings. S. F. Bowser & Company.

Centrifugal oil purifier for power house. De Laval.

### Use of Lignite as Fuel

The fact that lignite can be satisfactorily burned as domestic and boiler fuel when suitable stoves and grates are provided means that its use is restricted primarily by the advantage of other fuels in price, convenience, storage, bulk, and rate of combustion, states the Bureau of Mines, Department of Commerce. In the regions adjacent to lignite-producing mines storage is not important; relative price of available fuels is the determining factor. In such regions lignite is naturally the principal fuel used.

Because lignite contains a relatively high percentage of water, approximately 33 per cent, it does not follow that a low thermal efficiency will result from its combustion under a boiler. The actual loss due to the total heat carried away by the water passing out at the usual stack temperature is only 6 to 6.5 per cent of the total heating value of the lignite. Proper combustion facilities only are needed to obtain high thermal efficiency from lignite.

Bureau of Mines Bulletins 21, 40, 89 and 135, and Technical Papers 137, 205, 217 and 279 give complete details. Under test conditions a thermal efficiency of 80 per cent can be obtained by the combustion of lignite boiler fuels. The boiler capacity with this fuel will be less than with high-grade fuels unless large grates and furnaces are provided to accommodate the larger amounts of fuel and ash to be handled. With forced draft giving higher rates of combustion, and approved combustion conditions, the maximum capacity (boiler horsepower developed) is rarely over 140 to 160 per cent of the rated capacity unless a larger grate area is provided than that for bituminous coal. With large grates and furnaces and forced draft, 275 per cent of boiler rating has been attained.



## NEWS OF THE PLANTS

A new company known as the Bailey Meter Company on April 1 acquired the flow meter business and patents of the General Electric Company and the fluid meter and combustion control business and patents of the present Bailey Meter Company.

The engineering, manufacturing and sales organization of the present Bailey Meter Company will be retained by the new company, with the increase in personnel necessary from the General Electric Company to handle properly the additional business. The new company will have its factory and general offices in Cleveland, O.

E. G. Bailey, president of the present Bailey Meter Company, will be president of the new company. R. S. Coffin, vice president of the present Bailey Meter Company, will be vice president in charge of administration and finances. R. E. Woolley, now connected with the General Electric Company, will be vice president in charge of engineering and sales. The new Bailey Meter Company will offer a complete line of flow meters, boiler room instruments and combustion control equipment.

\* \* \*

R. H. Beaumont Company announce they have taken over the business of the American Manufacturing and Engineering Company of Kalamazoo, Mich., and products formerly manufactured by this company, including the American Slack Line Cableway Excavator, will now be manufactured by the R. H. Beaumont Company. Mr. S. O. Nafziger, president of the American Manufacturing and Engineering Company, will be associated with R. H. Beaumont Company.

The addition to the American Slack Line Cableway Excavator to the Beaumont line which already includes the Beaumont LeClair Cable Drag Scraper, completes a full line of equipment for the elevating and storing of sand, gravel, stone and kindred materials.

The R. H. Beaumont Company will sell the complete system for this service, including the hoist.

\* \* \*

The Charles Dreifus Company, Oliver Building, Pittsburgh, dealer in iron and steel scrap, has purchased the Runyon Steel Company, which is engaged in the same business at 1019 Beaver Avenue, Pittsburgh, North Side. The acquisition of the Runyon Company gives the Dreifus Company two yards in the Pittsburgh district.

\* \* \*

The Danville Structural Steel Company, Danville, Pa., formerly known as the Danville Structural Tubing Company, has acquired the local plants and business of the Pennsylvania Brake Beam Company, and the Penn State Steel Company, both of which have been idle for several weeks. The new owner will consolidate the acquired interests with its organization. Operations will begin at once at the two plants, to be given over to the fabrication of steel shapes, steel fence posts, reinforcing bars and rods, steel tubing, etc., in conjunction with the main plant of the purchasing company. The three mills will have an output of 3,000 tons per month. S. W. Bay is president

and general manager of the Danville Company; C. A. Weymouth, vice president; J. N. Pursel, treasurer; and M. E. Clover, secretary.

\* \* \*

Hickman, Williams & Company, Chicago, will discontinue the operation of its scrap yard in that city and will offer the equipment for sale. The company will continue in the brokerage business in Chicago.

\* \* \*

The Morgan Engineering Company, Alliance, O., has received an order from the Colorado Fuel & Iron Company for furnace and rolling mill equipment, which with other orders from this company, aggregates about \$1,000,000. The Morgan Company also has orders on its books from the Bethlehem Steel Company.

\* \* \*

The Carnegie Steel Company has appropriated \$1,250,000 for the improvement of its works at Farrell, Pa. About \$400,000 will be expended for a turbo-blower and electric generator at the blast furnace. The remainder of the appropriation will be utilized in purchasing a breakdown mill, between the blooming mill and the bar and billet mills.

\* \* \*

Plans for consolidation of the Superior Sheet Steel Company, Canton, O., with the Kokomo Steel & Wire Company, Kokomo, Ind., and the Chapman-Price Steel Company, Indianapolis, has been completed, for approval of stockholders.

The Superior and the Chapman-Price plants will acquire their raw materials from the Kokomo plant, which will produce steel for all three companies. The Kokomo plant now has open-hearth furnaces of 180,000 tons capacity, a modern electrically driven blooming mill of 400,000 tons capacity. The output of steel products such as billets, rods, wire, nails and fence approximates 120,000 tons a year. To meet the increase of orders as a result of the merger, the ingot capacity of the Kokomo plant will be increased to 250,000 tons immediately.

\* \* \*

Lawrence W. Cross, is president of the newly organized Continental Steel Corporation with offices at 604-5 Stephenson Building, Detroit, and warehouse at 5674 Twelfth Street. This company will act as a jobber of sheets, strips, bars and other steel products. Mr. Cross will continue to represent the Empire Steel Company of Cleveland in the State of Michigan. Arthur L. Tushbant, president of the General Steel Corporation, Detroit, is now secretary-treasurer of the new company.

\* \* \*

Research activities on a large scale are to be inaugurated by the United States Steel Corporation. The finance committee of the corporation has given its sanction. George Gordon Crawford, president. Tennessee Coal, Iron & Railroad Company has been made chairman of a special committee to organize a research department and erect a laboratory on a site to be selected.



## WITH THE EQUIPMENT MANUFACTURERS

### New Steel Mill Motors

A new line of steel mill motors, to be known as the MD-400 series, is announced by the General Electric Company. These motors, designed in collaboration with the standards committee of the association of Iron & Steel Engineers, fully meet the specifications of that body and are the first motors on the market to meet the new standards.

The motors are of the roller bearing type, in compliance with the standardization rules. The roller bearings will be used as standard, although sleeve bearings can be supplied at the option of the purchaser.

The new line involves improved mechanical construction, more efficient use of materials and a refinement of details, when compared with the superseded line of MD-100 motors. A greater adaptability to severe service conditions is also claimed. Parts are more accessible and, at the same time, are better protected. The bearing construction for either sleeve or roller bearings incorporates new and valuable features.

The outstanding qualities are listed by General Electric as follows:

- 1—Heating-resisting insulation (mica and asbestos) conforming to A.I.E.E. Class "B" insulation specifications.
- 2—Ability to commute high overloads.
- 3—Very low  $WR^2$  to permit exceedingly rapid acceleration and frequent reversals.
- 4—Ready accessibility of each part.
- 5—Great mechanical strength of individual parts and exceptional security of the whole structure.

### Howe Chain Company's Trucks Now Called "Jak-Tung" Trucks

The trade name "Jak-Tung," has been applied to the small, three-wheeled truck manufactured by the Howe Chain Company, of Muskegon, Mich.

The "Jak-Tung" Truck consists of a platform, equipped with two malleable iron wheels at the rear, and a malleable iron draw bar in the front. The jack tongue, from whence the truck takes its name (with wheel) hooks into the draw bar leg, and, by a downward thrust of the handle, the load is raised, and may be hauled anywhere.

Built in 17 different sizes and 3 models, with either steel or hardwood platforms or trays—in varied combinations—this truck obviously finds its greatest usefulness as a material conveyor in plants, handling loose, bulk, package, or heavy piece equipment up to 3 tons in weight.

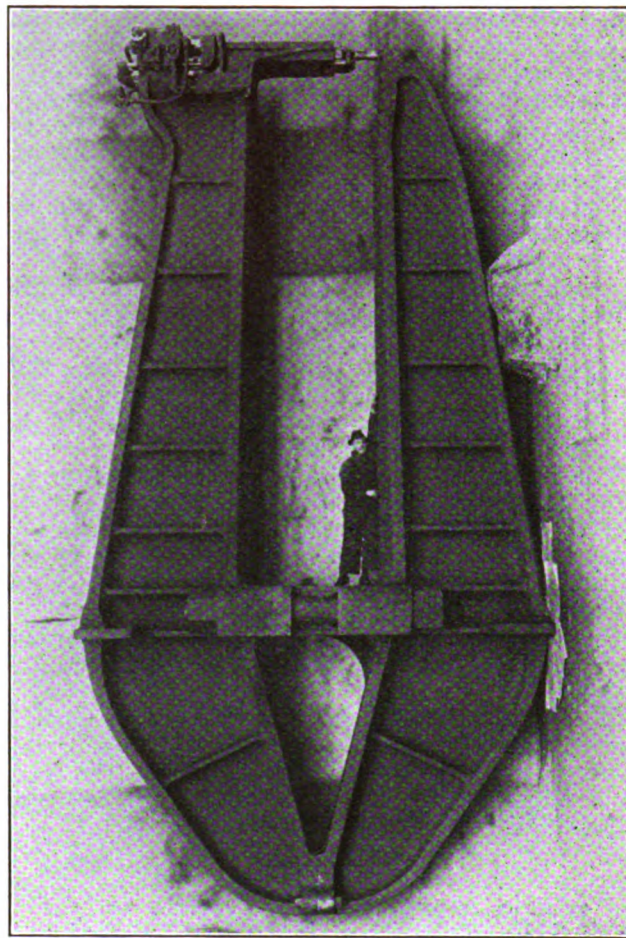
Features claimed for the "Jak-Tung" Truck are that, since materials are kept on wheels from one operation to the next, congestion and spoilage, in addition to the expense of double handling, are obviated.

It is declared that trains of eight or 10 "Jak-Tung" Trucks, together with a tractor, will wind around machines, turn sharp corners, negotiate narrow pathways, and in other ways function efficiently and "track" perfectly in congested quarters.

### A Giant Riveter

The largest hydraulic riveter ever built in this country has just been completed and shipped by the Chambersburg Engineering Company of Chambersburg, Pa.

This gigantic riveter has a shipping weight of 166,000 pounds. Its all-over length is 32 ft. and the gap is 20 ft.



The maximum rivet-driving capacity is 200 tons, but by means of the W. H. Derbyshire patented distributing valve this pressure may be controlled so as to exert 40, 80, 120, 160, or 200 tons as desired.

The accompanying photograph gives some idea of the dimensions of this huge riveter.

### New Westinghouse Disconnecting Switches

The Westinghouse Electric & Mfg. Company has recently placed on the market a new line of air-break disconnecting switches, that are gang operated and are for outdoor service. These switches may be operated as single, double or three pole units and are available for voltages of 7,500, 15,000, 25,000, 37,500, 50,000 and 73,000 and in capacities of 400 and 600 amperes. A 200 ampere rating is also available for the 7,500 and 15,000 volts.



Ease of installation and operation, and ruggedness of construction are the outstanding features of these new switches. The contact fingers on these switches are of self-closing type and have ample contact surface. Arcing horns are furnished with all upright mounted switches, but if not required may be discarded. The switches are also furnished for inverted and vertical base mounting. The operating mechanism is of the double toggle type, with arrangement for padlocking in both positions.

### Link-Belt Company Announces Novel Product

Of interest to all manufacturers whose processes or fabrication require the use of grease cups, should be the announcement of Link-Belt Company, of Chicago, Indianapolis, and Philadelphia, which describes their new "Hex-Top" Malleable Iron Compression Grease Cup with Alemite, or Zerk fittings.

The trade name "Hex-Top" describes very aptly the shape of the grease cup head. Six-sided, it offers, for turning, an easy purchase for any type of wrench, and a good grip for the hand.

The combination of compression grease cup and Alemite fitting is a distinct improvement over either article used separately.

An example of this would be in the lubricating system of a long belt conveyor using many grease cups for the idlers: Here the easiest, quickest, and most economical way to fill all the cups at one time, it is said, is with a grease gun applied to the Alemite fitting, when the cap is turned up to a high point, but not entirely unscrewed or removed.

The filling can be done without waste of grease, and without any inconvenience; the cup holds a good reserve for use of the compression feature; and an occasional slight screwing down by hand or wrench is all that is necessary until it is time to have a general refilling of the cups.

If a bearing gets warm when the grease gun is not at hand, a turn or so of the cap takes care of the emergency.

The fact, moreover, that the cup may be readily filled in even the most inaccessible places—for relegation to such locations seems to fall to the lot of the lowly grease cup is due to just as great an extent to the "Hex-Top" head as to its fittings.

### Practical Metal Railroad Ties Made From Scrap Rails

Metal railroad ties, constructed by electric arc welding from worn rails, are not only ten times as strong as ordinary wooden type of tie, but can be made at a very low cost, according to William Dalton of the General Manufacturing Department of General Electric Company. Mr. Dalton recently completed a test extending over a period of a year in collaboration with H. S. Clarke, engineer, Maintenance of Way, Delaware & Hudson Railroad.

A number of sample ties were installed by the D. & H. about a year ago in its Glenville Yards. The test has been so successful that Vice President Loree has decided to undertake the substitution of metal for wooden ties in yards and sidings, and arrangements are now being made by that railroad company to install equipment in its shops for the construction of the ties.

The tie design as worked out by Mr. Dalton, involves the use of two pieces of rail for each tie. The rail used is that which has been removed from the roadbed as worn and has no value except as scrap. The two lengths are fastened together at each end by metal plates welded in position. The L-shaped angle bars used in ordinary rail joints can be used for this purpose. When two rails are fastened together in this manner, movement of the tie in any direction in the ballast is eliminated.

### Slush Pump

The Wilson-Snyder Company, of Pittsburgh, Pa., is offering a new Slush Pump for deep drilling. The pump, which is designated as No. 18, was designed to meet the demand for a slush pump for deep hole rotary drilling in the oil fields.

## COMING MEETINGS

May 12-14—American Gear Manufacturers' Association. Eleventh annual meeting at Hotel Hayes, Jackson, Mich. T. W. Owen, 2443 Prospect Avenue, Cleveland, is secretary.

\* \* \*

May 18-19—American Refractories Institute. Spring meeting at Hotel Traymore, Atlantic City, N. J. M. C. Booze, 2202 Oliver Building, Pittsburgh, is secretary.

\* \* \*

May 19-20—American Society for Steel Treating. Spring sectional meeting at Milwaukee. W. H. Eisenmann, 4600 Prospect Avenue, Cleveland, is secretary.

\* \* \*

May 21—National Association of Foremen. Fourth annual convention at Cincinnati Zoo, Cincinnati. E. H. Tingley, 1249 U. B. Building, Dayton, Ohio, is secretary.

\* \* \*

May 23-26—American Society of Mechanical Engineers. Spring meeting at White Sulphur Springs, W. Va. Calvin W. Rice, 29 West Thirty-ninth Street, New York, is secretary.

\* \* \*

May 25-26-27—The fourteenth annual convention of the Foreign Trade Council at Detroit, which promises to be one of the most profitable and outstanding business conventions held in America this year.

The Power River Company of Vancouver, Canada, has installed a combination of General Electric control devices and warning signals to prevent failure of the lubricating system for its electric generator, and to prevent overheating of the generator thrust bearing. On failure of the oil pump, a spare pump is immediately started and an industrial signal sounded, and a signal sounds when the thrust bearing overheats.

The oil pump which is regularly used during the operation of the generator is driven through gearing from the generator shaft. An independent motor-driven oil pump is also provided with an equipment for hand starting. Should the geared pump fail to operate, the motor-driven pump will go into service automatically.



# SAFETY FIRST IN THE STEEL PLANT

Section Devoted to the Interest of the Safety Movement

The "Safety First" movement has gained such a momentum in our Steel Plants that it must be accorded wider recognition. With a desire to lend active support to this worthy movement, The Blast Furnace and Steel Plant inaugurates, with this issue, a section devoted to matters pertaining to "Safety First." While the section starts with only one page it is the intention to increase the space in later issues.

## Safety Means More Than Mechanical Guarding

In the early years of industrial safety work, it was looked upon almost entirely as a mechanical engineer's job. Safety in a plant meant the guarding of belts and gears, the removal of square-headed set screws, the safe equipment of machines and the improvement of physical conditions.

A careful study of the accident experience of any industry or of industry as a whole will indicate that today not over 15 per cent of accidents are mechanically preventable. Most result from lack of knowledge or care on the part of individual employees.

Although a program of safe-guarding and physical improvement is essential as proof of the company's interest in accident prevention, the safety problem is largely one of education and the development of definite and continued interest among the employees.—Metropolitan Life Insurance Company.

## Officers of the National Safety Council

Metals Section—Chairman, F. G. Bennett, The Buckeye Steel Castings Company, Columbus, Ohio; Vice Chairman, J. A. Northwood, Bethlehem Steel Company, Johnstown, Pa.; Secretary, E. G. Quesnel, Commonwealth Steel Company, Granite City, Ill.; Chairman Program Committee, John P. Eib, Illinois

Steel Company, Joliet, Ill.; Chairman Bulletin Committee, Frank H. Rowe, Wheeling Steel Corporation, Portsmouth, Ohio; Chairman Membership Committee, H. G. Hensel, The Youngstown Sheet & Tube Company, Chicago, Ill.; Engineering Representative,

Earl P. Blank, Jones & Laughlin Steel Corporation, Pittsburgh, Pa.; Executive Committee, the Officers and A. C. Gibson, Spang, Chalfant & Company, Pittsburgh, Pa.; T. H. McKenney, Illinois Steel Company, South Chicago, Ill.; John Oartel, Carnegie Steel Company, Pittsburgh, Pa.; J. M. Woltz, The Youngstown Sheet & Tube Company, Youngstown, Ohio.



The Safety Trophy of the Carnegie Steel Company, which is to be put into competition in its 11 plants, during 1927, has been completed and delivered to that company and is now being displayed throughout its plants.

The National Safety Council advises that at the present time there are 99 applications on file in the office of the National Safety Council. Fifteen of these applicants are desirous of locating in the metal industry either because their past experiences have fitted them for it or because they have inherent liking for that following.

For information regarding any of the applicants, address: The National Safety Council, 108 E. Ohio Street, Chicago, Ill.

"Getting Results from Safety Work," a recent publication issued by the Policyholders' Service Bureau of the Metropolitan Life Insurance Company, presents for the attention of the executive, an effective series of facts and figures showing the results obtainable from a successful safety program. This booklet is addressed to the Chief Operating Official since it is he who must assume active leadership of plant safety activities if results are to be obtained. Those interested in the problem of safety may obtain a copy of "Getting Results from Safety Work" by writing to the Policyholders' Service Bureau of the Metropolitan Life Insurance Company.



# THE STEEL PLANT BRICK MASON

A Section Devoted to Items of General Interest to Blast Furnace and Steel Plant Brick Masons

## Meeting of American Refractories Institute Atlantic City, N. J., May 18, 1927

Meeting will be held on Wednesday, May 18th, Hotel Traymore, Atlantic City, N. J., to be followed by a golf tournament on Thursday, May 19th. Everyone interested in the manufacture or use of refractory materials is invited to attend. A buffet luncheon will be served on the day of the technical meeting and in the evening there will be a dinner, to which special speakers have been invited. Reservations for this dinner should be made in advance through the Secretary's office, 2202 Oliver Building, Pittsburgh, Pa.

Mr. M. C. Booze is well known to those in the Refractories industry and his talk will be of general interest.

For the last half year the Refractories Fellowship has been conducting investigations on control of grain size of clay refractories and it is believed that this study, although incomplete, will probably lead to the greatest development that could be expected in clay refractories.

The questionnaire phase of the program is new and it is hoped that those having something to offer on any of the questions will come to the meeting prepared to give a short discussion. We are arranging to have one or two individuals, chosen particularly for their authority on their particular question, to start the discussions, after which they will be open for general discussion.

1—"Research in the Refractories Industry," by M. C. Booze, Vice President, Chas. Taylor Sons Company, Cincinnati, O.

2—"Properties of Clay Refractories Resulting from the Control of Grain Size of the Flint Clay," Refractories Fellowship, Mellon Institute.

3—"Some Characteristics of Fire Clays and Brick Made From Them," by R. F. Geller, Bureau of Standards, Washington, D. C.

4—"The Effect of the Use of Purite Upon Refractories," by G. S. Evans, The Mathieson Alkali Works, Chicago, Ill.

5-Discussion of the following questions:

What does the industry need in the way of technical development?

Is the Ceramic Engineer as at present being turned out by the Department of Ceramic Engineering satisfactorily serving the refractories industry? In what respect is his training lacking?

What is the proper type of machine for grinding raw plastic clay to 60-mesh and finer?

What are some practical methods for preventing the coarse particles of clay from separating from the fine clay in storage bins? To what extent does this separation affect the properties of the finished brick?

What are the benefits to be derived from using hot water in the tempering of clay mix instead of cold water?

What is the best type of dust collector for dry pans?

What is the cause of convex surfaces on hand molded shapes and how may same be prevented?

Humidity drying of tile shapes of large size vs. hot floors, including initial costs of both installations, operating costs and time to dry. What of spoilage?

What might be considered good average and medium amount of coal to burn 1,000 9 in. equivalents?

Rectangular kilns;

Round kilns;

Tunnel;

High heat, intermediate, moderate, low duty brick.

At what particular stage or stages in burning does "kiln marking" occur and how may it be best controlled?

Is there any material difference in cost between dry pressed and stiff mud fire brick?

Why are so many difficult shapes required in refractories?

What is the cause of surface checking or crazing of refractories and how can it be overcome?

What is the best refractory for use with coals high in ash with two to four per cent iron content (Illinois coal)?

What types of refractories are best suited for puddling furnaces?

A test for determining the resistance of first quality clay brick to the action of abrasion.

The accurate determination of reversible coefficient of expansion of fire brick at all temperatures up to 2,400 deg. F. and the practical value



"Bill" Isaacs, Assistant Superintendent of Masons, at the Youngstown Sheet and Tube Company, is a very busy man, but consented to step over to the brickshed for the above photograph. Mr. Isaacs has seen long service in the masonry department at Youngstown Sheet and Tube Company, and he, like those formerly mentioned on this page, can be placed in the veteran class.



of having and using the result in designing boiler furnaces.

Spalling of fire brick in boiler furnaces. How many different kinds of spalling are there, and how can one distinguish between the various kinds?

Reports on mullite brick under severe service, including reports on failures.

Determination of mullite content.

Plastic refractories.

Uniform cost system. Credit bureau. Production and Sales statistics.

## Refractory Materials for Metal Furnaces

By Walter J. May\*

Chromite and magnesia bricks are about the most refractory, as they fuse at 3700 deg. F. and 3900 deg. F. respectively, ordinary fireclay bricks in good examples standing up to about 3100 deg. F., but usually much less, often 2800 deg. F. being as much as they will bear safely.

Taking the firebricks more generally used, it will be found that the approximate melting or fusing points are as under, some differences occurring according to make of brick, nature of fuel used, and other minor details:

| Nature of Firebrick | Fusing Temperature |                  |
|---------------------|--------------------|------------------|
| Fireclay .....      | 1555 to 1725° C.   | 2831 to 3137° F. |
| Bauxite .....       | 1565 to 1785° C.   | 2849 to 3245° F. |
| Silica .....        | 1700 to 1705° C.   | 3092 to 3101° F. |
| Chromite .....      | 2050° C.           | 3722° F.         |
| Magnesia .....      | 2165° C.           | 3929° F.         |

The clays from which these bricks are more or less made do not give quite the same results, and for some kinds of furnace work give an idea that they could be used to more advantage if, after being tempered, they were rammed up to form the walls of the furnace, and, after allowing time for drying, were fired *in situ*. In some cases this might be a feasible proposition, but as contraction and cracking during both drying and firing would take place, it is doubtful whether there would be much advantage. Of course, in the case of small furnaces the use of tubes or entire linings show advantages, but these must be made and fired before they are placed in position, and the backing must be dry before the furnaces are used. As jointing, however, it is well to use practically the same material as the bricks, a silica brick having a silica joint, and so on. By comparing the fusing points of the clays, as under, with that of the refractory bricks previously given, it will be seen that if the workmanship is good a properly jointed furnace should wear nearly level on the fire side:

| Nature of Clay     | Fusing Temperatures |                  |
|--------------------|---------------------|------------------|
| Kaolin .....       | 1735 to 1740° C.    | 3155 to 3164° F. |
| Bauxite .....      | 1820° C.            | 3308° F.         |
| Bauxite clay ..... | 1795° C.            | 3263° F.         |
| Chromite .....     | 2180° C.            | 3956° F.         |
| Pure alumina ..... | 2010° C.            | 3650° F.         |
| Pure silica .....  | 1750° C.            | 3182° F.         |

Besides these natural refractories, carborundum, 2700 deg. C. (4860 deg. F.), and alundum, 2050 deg. C. (3722 deg. F.), are at times used in block form for very small furnaces, carborundum probably standing as high a temperature as can be secured from carbon under blast; but these substances would scarcely be

used for other than experimental work on account of cost.

In the erection of furnaces it is necessary that bricks or blocks should be square on the edges to enable the thinnest possible joints to be made, and radius or "arch" bricks should be flat on the sides where the joints are made, so that thin joints are possible. The jointing clay should be smooth and thin, so that when the bricks are put together they can be rapped down to have as thin a joint as possible,  $\frac{1}{8}$  in. being quite enough, while even less would be better if the clay will work down and the bricks are thin enough. In all cases the face of the work must be smooth where the fire reaches it, and particularly is this necessary where high temperatures have to be withstood. Fire does not attack a smooth surface so readily as it does a rough one, and it is always the edges of the bricks which go first.

For outside brickwork it is often desirable to use plastic material, as in ramming up a cupola with finely ground ganister. This, if fine enough, when well rammed into position will, after drying, make a good lasting lining for iron, and if the kind used in steel-furnace work is chosen, will last nearly as long as good fireclay bricks, provided it is finished with a smooth surface. Portable furnaces are also frequently lined with this fine ganister very successfully, and answer well, but finely ground material is not always to be had in small parcels as required by amateurs or small users.

A very good lining for small furnaces can be made by crushing old plumbago crucibles, free from slag, so that the material will pass a 3/16-in. square-meshed sieve, and adding to this about a fifth part of china-clay, or, if this is not to be had, pipeclay as used in making common tobacco pipes, the clay being dry and crushed to pass the same sieve as the crucible material. This has to be thoroughly mixed and damped down until it will form a stiff plastic mass or dough, and should then be rammed or beaten into position, and, after smoothing the surface, allowed to dry naturally. If gradually fired at the first heating until it is fully red hot, this material stands well, and though usually it costs a mere trifle it is worth the trouble of preparing. In the event of china-clay or pipeclay being unobtainable, a good aluminous clay free from silica can be used as a makeshift, but it does not answer so well, nor will it stand so great a heat. Large grains of the material must be avoided, or the mass is likely to blow apart when heated.

Otherwise good material for refractory work is often spoiled by the presence of soda, lime, potash, or other fluxing substance, and before largely using any clay or other natural deposit it is advisable to have a complete analysis made, because refractory materials holding a fluxing medium are really valueless when put into practical use. This is too often overlooked when deposits of earths or sands are found; and disastrous results often follow.

Expansion and contraction have also to be considered, as these are unavoidable where fluctuations of temperature occur; and all materials do not expand alike with heat, it must be remembered—firebrick and iron, for instance, having different rates of expansion. For this reason a rather free fit is necessary when lining up portable furnaces, and where the lining is put in as a plastic mass care should be taken that it does not adhere to the iron casing. This does not apply to lining or daubing cupolas, or the like.

\*Mechanical World, Manchester, England.





Keith D. Graham who in 1926 became connected with The Root Company, Bristol, Conn., in capacity of stock clerk has just been elected secretary of the company. Mr. Graham has been in charge of production of the Root plants for the last year or so. The Root Company manufactures automatic counters, hinges, butts, stampings, bottle openers, etc.

\* \* \*

Frank Jarosch has just taken charge of the Engineering department of the S. B. R. Specialty Company, general offices and works, East Orange, N. J. Mr. Jarosch graduated in Europe as a mechanical engineer and has been continuously connected with the ball and roller bearing industry since 1907. After several years of bearing research work with the D. W. F. Company, manufacturers of D. W. F. Ball and Roller Bearings of Berlin, Germany, he became Consulting Engineer to the F. & S. Bearing Factories, the largest ball bearing manufacturer in Europe. He was a member of the Society of Automotive Engineers and served on the S. A. E. Standards Committee for a number of years.

\* \* \*

S. R. Morris, secretary and treasurer Steel Plate Products Company, Pottstown, Pa., has been elected president of that company to succeed P. L. Keiser, whose interest he has purchased. Mr. Morris was identified in metallurgical and engineering capacities for some 10 years with the National Tube Company and other companies in the Pittsburgh district, and in 1917, joined Mr. Keiser in organizing the Pottstown company.

\* \* \*

L. B. Lindemuth, of Carney & Lindemuth, 40 Wall Street, New York, sailed for Australia, March 30. He is planning to remain in Australia six or eight months in the interest of the Broken Hill Proprietary Company, Ltd., New Castle, New South Wales.

\* \* \*

Lawrence W. Cross, formerly district manager for the Empire Steel Company, Cleveland, is now the president of the Continental Steel Company, Detroit. He was at one time purchasing agent for the Fisher Body Corporation.

Charles F. Humpton, secretary and treasurer of the Lukens Steel Company, Coatsville, Pa., has resigned. He was with this company 26 years, and has filled the position of secretary and treasurer since the death of his father, Joseph Humpton.

\* \* \*

J. K. Baylis, for some years in the sales department of the Donner Steel Company in Philadelphia, has been appointed manager of structural and plate sales at Buffalo for the Bethlehem Steel Company.

\* \* \*

Frank A. Mitchell, representative for the past four or five years for Newport Rolling Mill Company, Newport, Ky., is also representative for the Andrews Steel Company of Newport and affiliated with the Newport Rolling Mill Company. His headquarters are at 809 Bulkley Building, Cleveland.

\* \* \*

Ledyard Heckscher, president of the Alan Wood Iron & Steel Company, Philadelphia, returned March 14 from a cruise in the West Indies.

\* \* \*

W. L. O'Connell, assistant manager of sales for the Thomas Sheet Steel Company, Niles, Ohio, has been named district manager of sales for the company at Detroit, and is establishing new sales offices there for the Thomas Company in the General Motors Building.

\* \* \*

W. H. Donner, president of the Donner Steel Company, Inc., Buffalo, has been elected a director of the United States Glass Company, Pittsburgh.

\* \* \*

David E. Williams has been elected a director of the Cambria Iron Company, succeeding the late Powell Stackhouse, who died February 4 at St. Petersburg, Fla.

\* \* \*

Curtis B. Friday has been appointed sales engineer of wheels and forgings in the rail bureau of the general sales department, Illinois Steel Company, Chicago. Norman M. Hench has been appointed sales engineer of track accessories in the rail bureau.



Mr. H. B. Newell has been elected vice president and director of the Fawcus Machine Company. Mr. Newell, for several years, has been works manager.

\* \* \*

H. W. Brooks, formerly consulting engineer for the Fuller-Lehigh Company, Fullerton, Pa., is now with the Erie City Iron Works, Erie, Pa.

\* \* \*

Alex. L. Field, until recently a member of the metallurgical staff of the Central Alloy Steel Corporation, Massillon, Ohio, and for some years previously with the United Alloy Steel Corporation, is now associated with the Electro Metallurgical Company and the Union Carbide & Carbon Corporation, with headquarters at 30 East Forty-second Street, New York.

\* \* \*

Herbert W. Spencer, superintendent of the Bessemer department, Joliet works of the Illinois Steel Company, Chicago, has retired after 39 years of service with that company. He was born November 15, 1860, and in 1887 joined the Joliet Iron & Steel Company as an employee in the Bessemer department. On May 1, 1900, he was advanced to superintendent of the Bessemer department, which position he held until his retirement.

\* \* \*

Joseph H. Roberts, for three years Eastern sales manager Vanadium Alloy Steel Company, Latrobe, Pa., and formerly vice president of the Atlas Steel Corporation, Dunkirk, N. Y., has resigned and is now interested in the Edgcomb Steel Corporation, Newark, N. J., being vice president and general manager of sales of this company.

\* \* \*

G. F. Elliott recently was elected vice president and assistant to the president of the Elliott Company, Jeannette, Pa. He was also made general manager of the Ridgway Dynamo & Engine Works of the company. R. N. Ehrheart is vice president in charge of engineering for the Elliott Company.

George P. Rhodes, vice president Colonial Steel Company, Pittsburgh, has been elected president of the company. He succeeds the late Charles M. Brown. Mr. Rhodes has been prominent in the iron and steel industry at Pittsburgh for many years, his first connection having been with the Pennsylvania Tube Works, now a part of the National Tube Company.

\* \* \*

Harvey L. Spaunberg, superintendent of manufacture of The Root Company, Bristol, Conn., manufacturers of automatic counters, hinges, butts, stampings, bottle openers, etc., has just been elected a director of the company. Mr. Spaunberg has been connected with the Root Company since the war, having been in entire charge of the designing and manufacture of the automatic counters.

\* \* \*

Wadsworth Doster, formerly sales manager of The Torrington Manufacturing Company, Torrington, Conn., has been appointed, effective April 1, assistant sales manager of cold strip machinery department by Mackintosh-Hemphill Company, Pittsburgh, Pa., who are offering the latest developments in four-high and two-high cold mills; heavy duty reels, roll coilers, wide slitters, high-speed trimmers, straightening equipment, shears and other auxiliaries. Mr. Doster, was manager of the Blake & Johnson Company, Waterbury, Conn., before it was merged with The Torrington Manufacturing Company.

\* \* \*

Henry M. Robinson, president of the First National Bank of Los Angeles, was elected a director of the General Electric Company at the meeting of the board in New York on March 25. In addition to his position with the First National Bank, Mr. Robinson is president of the First Securities Company, chairman of the board of the Pacific Southwest Trust & Savings Bank, and a director in a number of other large corporations. This is the first time the General Electric Company has gone to the West for a member of its board.



## TRADE PUBLICATIONS

The Inland Steel Company, 38 South Dearborn Street, Chicago, is distributing a 6-in. x 3¼-in. booklet, containing information descriptive of the various grades of sheet steel manufactured by the company. The characteristics of each grade is presented in such a manner as to simplify selection for any particular purpose. "Extras" and "differentials" are tabulated, while sizes and other data are given in detailed form. The size and arrangement of the booklet will appear to those who have use for this information.

\* \* \*

The Air Reduction Sales Company, 342 Madison Avenue, New York City, has available, in pamphlet form, a reprint of a paper "Pipe Line Welding from the Oxy-acetylene Viewpoint" presented at the meeting of the American Welding Society, on December 21, 1926. Mr. LeRoy Edwards is the author. The pamphlet is well illustrated.

\* \* \*

"A Thermodynamic Analysis of Internal-Combustion Engine Cycles" is the subject of a bulletin issued by the University of Illinois, Urbana, Ill. This is a treatise on the theory of internal-combustion engine operation and will prove of interest to those with experience in higher mathematics. It is a very complete study of the Otto and Diesel cycles.

\* \* \*

The Reliance Electric & Engineering Company, Ivanhoe Road, Cleveland, has prepared Bulletin No. 200 describing type "T" Heavy Duty Motors for d.c. Illustrations assist in making the descriptive matter readily comprehensible. Photographs show the motors as applied to various types of equipment.

\* \* \*

"The Wabblor" is the name of a leaflet, published by the Mackintosh-Hemphill Company of Pittsburgh; copies of which have recently been distributed. Judging from the initial issue "The Wabblor" should prove of much interest to those engaged in the design and use of rolls. The Mackintosh-Hemphill Company was one of the first to engage in the manufacture of rolls and hence is well qualified to sponsor such a publication.

\* \* \*

The twenty-fifth annual report of the United States Steel Corporation contains much information other than that concerning its financial status. In the production of ingots there was a gain in 1926 of 7.5 per cent as compared with 1925, and a similar gain in rolled and finished products of 8.0 per cent. The total production of Bessemer and open-hearth ingots in 1926 was 20,306,068 tons and of finished products, 14,334,412 tons. Total value of business in 1926, covering all products, reached \$886,710,521 for domestic shipments and \$100,426,645 for export shipments.

\* \* \*

"Steel Never Fails" is the title of a booklet being distributed by the American Institute of Steel Construction. This booklet mentions 14 reasons for the sentiment expressed in the title and throughout the pages elaborates on each reason with the aid of illustrations. The illustrations are especially pleasing.

A copy will be forwarded without cost, to any who may request it. Address, 285 Madison Avenue, New York City.

\* \* \*

The American Society of Mechanical Engineers has mailed a pamphlet in which are outlined the conditions governing the award of Lincoln Arc Welding Prizes, for 1927. Those interested in competing for these prizes should address Calvin W. Rice, secretary, 29 West Thirty-ninth Street, New York City.

## TRADE NOTES

The Cleveland district offices of Combustion Engineering Corporation, Ladd Water Tube Boiler Company and Heine Boiler Company have been consolidated and will be located at 1107 Guardian Building. Mr. Frank Henderson is Cleveland District Manager of these three associated companies.

\* \* \*

The General Electric Company has recently opened a service shop and warehouse in Buffalo, N. Y., for the purpose of serving the electrical industry in the western part of the state. The building is of modern brick and steel construction with a saw tooth roof and a large number of steel sash windows which makes it possible to work by daylight in practically every part of the building. There are approximately 25,000 sq. ft. of floor space, divided equally between the warehouse and service shop, all floored with wood block.

\* \* \*

As a result of election of officers during the tenth annual meeting of the National Slag Association held at the Old Colony Club, Cleveland, Ohio, on April 8, the following officers were re-elected for the ensuing year: Mr. C. L. McKenzie, president, Diamond Bank Building, Pittsburgh, Pa.; Mr. C. E. Ireland, vice president, Age Herald Building, Birmingham, Ala.; Mr. H. J. Love, secretary-treasurer, 933 Leader Building, Cleveland, Ohio.

\* \* \*

The Chambersburg Engineering Company, of Chambersburg, Pa., manufacturers of forging hammers, presses, riveters, pneumatic and hydraulic machinery, announce the opening of offices at 613 Machinery Hall, 549 West Washington Street, Chicago, under the direction of Mr. D. M. McDowell.

\* \* \*

The installations of superheaters, economizers, water-cooled furnaces and unit coal pulverizers, such as are manufactured by the Power Specialty Company, have increased to such proportions that an office in the southern territory was imperative.

Mr. J. W. Lea has been placed in charge of the Atlanta office of the Power Specialty Company, located at 315 Bona Allen Building, which will serve the states of South Carolina, Georgia, Florida, Alabama and most of Tennessee. Engineering estimates and advice will be gladly furnished, and drawings made for proposed installations in accordance with usual practice.

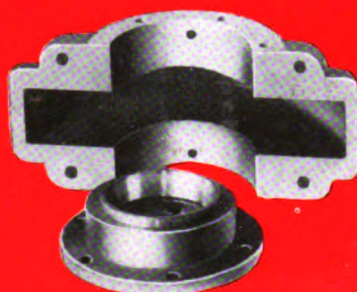
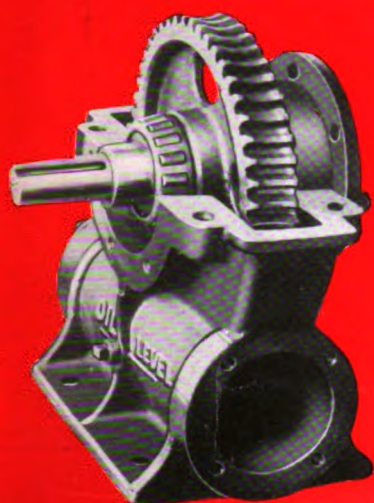
MAY 6 1927

# The Blast Furnace *(and)* Steel Plant

Enter of the Audit  
Bureau of Circulations

PITTSBURGH, PA., MAY, 1927

Entered as second class mail matter at Pittsburgh,  
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MILWAUKEE, WISC.  
PORTLAND, ORE.  
SAN FRANCISCO, CALIF.  
NEW ORLEANS, LA.  
BOSTON, MASS.  
MONTREAL, CANADA

149 Broadway  
G. R. Mueller Co.  
L. E. Meidinger  
Coast Steel Machinery Co.  
K. W. Eichelberger  
Southern Engineering & Supply Co.  
15 Exchange Street  
Hicks & Newill, 189 St. James St.

